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Closer university/industry links forged in Europe
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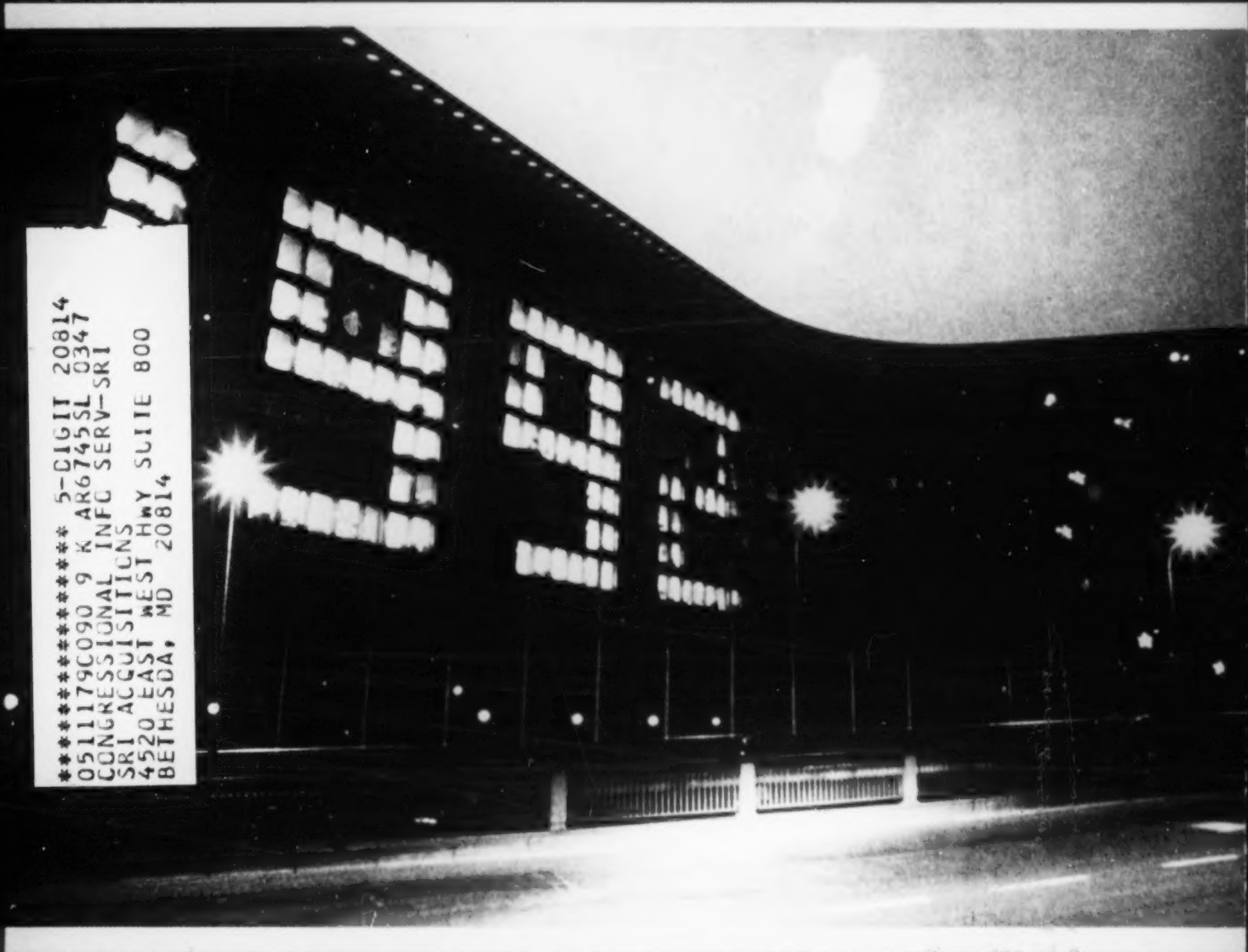
NOVEMBER 6, 1989

CHEMICAL & ENGINEERING NEWS



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European Community in 1992

U.S. chemical companies weigh
opportunities and challenges
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CHEMICAL & ENGINEERING NEWS

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NOVEMBER 6, 1989

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Cover: European Community headquarters in Brussels. Photo courtesy of EC Delegation, Washington, D.C.

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LETTERS

CHEMICAL SAFETY

Disposing of explosive salts

SIR: Due to a recent article in *Science* by W. L. Faust [**245**, page 37 (1989)] indicating that cyanate and thiocyanate salts can be explosive, I warn as I did in C&EN (Feb. 16, 1985, page 2) that these compounds under certain disposal conditions cannot be considered low hazard anions as listed in the National Research Council book, "Prudent Practices for Disposal of Chemicals from Laboratories."

In view of this article, a prompt revision seems necessary, and possibly past bulk disposal of some cyanate wastes may require further examination and recoveries to redispose properly. Besides the explosiveness, cyanate is easily converted back to cyanide complexes by ferrous ion, common in plumbing lines, and the complexes are listed as high hazard anions in the NRC book. Also, some tests that I have run using bleach diluted 10-fold to mix with diluted cyanate as might occur in drain lines have indicated no loss in oxidizing power despite an excess of cyanate.

This procedure, often used to completely destroy cyanide, did not cause nitrogen evolution as claimed, and led to a very pungent acrid odor (ClNCO?) being emitted. Consequently, several problems can occur in the disposal of these salts requiring their being listed as high hazard anions, and the ACS committee on hazardous wastes disposal should take appropriate steps to warn against casual disposal of cyanates and thiocyanates. Also the procedure in the NRC book for cyanide disposal probably should be altered, as it leads to cyanate plus some excess of bleach.

James A. Singmaster III
San Juan, P.R.

Chemical bonding

SIR: Chemical bonding is at the very heart of chemistry. A real understanding of chemistry is impossible without a good understanding of chemical bonds—the essential missing link in the long-sought integration of theory with descriptive chemistry. Unfortunately, few if any of today's students can acquire such an understanding from their textbooks, because these books are badly out of date in important aspects of bonding. We wonder why so many of our most talented students elect to major in something else. I think it is because, being intelligent and thoughtful, they prefer to devote their energy to something that makes more sense. True learning is a blend of memorization with understanding, and understanding is woefully lacking in today's presentation of chemistry.

This is tragic. In the face of mounting evidence that our educational system is notably deficient in science, it is especially tragic. The tragedy is magnified by the fact that this deficiency in chemistry teaching is unnecessary, and has been so for more than 20 years. Experts agree that the presentation of chemistry should provide a smooth blend of theory and practice. Such a blend has never been achieved, because theory, as monopolized by quantum mechanics, is inherently unsuitable for simple classroom explanation, and because there has existed a large and highly significant void in the understanding of chemical bonds that more than 60 years of quantum theory has failed to fill. For more than two decades, that void could have been filled by acceptance of a simple theory of polar covalence that has no conflict with quantum theory but merely does what quantum theory cannot do and perhaps may never do—provides a simple, quantitatively accurate explanation of chemical bonds in terms of atomic properties caused by structure.

The current presentation of bonding is seriously defective in these important aspects:

- Frequently the significance of the electronic structure of "noble gas" atoms is badly misrepresented.
- The treatment of the concept of electronegativity is extremely inadequate and misleading, and the thoroughly validated partial charges obtained from it continue to be ignored,

Correction

- Sept. 18, page 24: The reference to "Scheuer and Miller" in column three should have read "Scheuer and Moore."

U.S. Chemical Companies Ponder Europe after 1992

European Community's plan to create single market could mean big new opportunities for U.S. chemical industry, though concern persists that rules shaping EC-92 will discriminate against U.S., other foreign firms

Earl V. Anderson, C&EN Northeast News Bureau

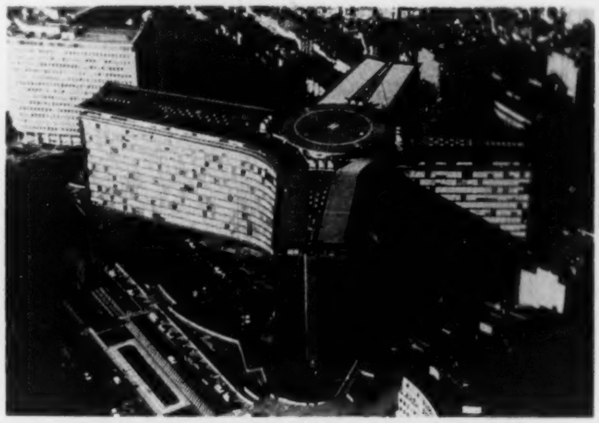
EC-92 isn't exactly a household word in the U.S. But there's no doubt that it's well known throughout the corridors of U.S. industry, including the internationally oriented chemical industry.

EC-92, of course, refers to the European Community's sweeping and ambitious plan to remove internal trade barriers and to create a single, harmonized European market by the end of 1992. If EC-92 shapes up as planned, the EC will become the largest single integrated market in the world. It is the 12-nation community's answer to the inflation, low economic growth, and high unemployment that plagued Europe in the early 1980s. This European economic stagnation became so bad that it earned the dubious nickname "Eurosclerosis."

Many sensitive issues still are unresolved. But one thing is certain. By 1992, a new, different, and more integrated EC will be emerging. Generally, EC industries, including its chemical industry, strongly support EC-92. And although the leaders of some member countries are reluctant to surrender pieces of their "national sovereignty" to a multinational body, EC officials label EC-92 "irreversible."

Willy De Clercq, former EC commissioner for external relations and trade policy, calls EC-92 "the biggest deregulation exercise in the history of Europe." Certainly, many EC hopes are riding on it. One EC study estimates that the community's gross domestic product (GDP) will be 4 to 6.5% higher than it would be without EC-92. It should create an estimated 5 million sorely needed new jobs. It already has triggered a wave of corporate restructuring, mergers and acquisitions, joint ventures, and cross-marketing agreements. Both public- and private-sector demand for goods and services should rise markedly.

The enormous business potential of a unified European market with a population greater than that of the U.S. (320 million) and a combined gross national product of $4.6 trillion hasn't escaped the notice of U.S. chemical companies or U.S. government officials. Neither have the possible problems that could develop for U.S. business if the rules, or directives as they are called in the EC, that shape EC-92 have a distinctly "European" bias and discriminate against U.S. and other foreign companies.



EC Delegation, Washington, D.C., photo

European Community headquarters in Brussels

U.S. Trade Representative Carla A. Hills says the question that concerns the entire world is whether the barriers lowered within Europe will be raised around Europe. Whichever way that ball bounces, U.S. chemical companies and their trade associations are busy preparing for a Europe that will be dramatically different after 1992 than it has been in the past. Although industry leaders are quick to point out a vast array of potential problems, most of them concede that the opportunities far outweigh the pitfalls.

Richard E. Heckert, who retired in April as Du Pont's chairman and chief executive officer, is optimistic about EC-92. "A larger, more affluent, and more integrated European market has to be a more attrac-

Ambitious EC-92 program was more than 40 years in the making

EC-92 is the catch-phrase for an ambitious program that the European Community has launched to unify its 12-country internal market. By doing so, EC leaders hope to bring an end to the economic malaise, or "Eurosclerosis," that had gripped Europe in the early 1980s.

A single internal EC market, they believe, will spur economic growth and make European companies more competitive, not only against imports but also in other world markets. To achieve this single market, EC-92 will remove all internal barriers to the free movement of goods, services, capital, and people among the 12 EC member nations. EC officials now call the single market process "irreversible." Although much has been done, there's still a long way to go before EC-92 becomes a reality. By implementing EC-92, the EC has rededicated itself to the original goals of the Treaty of Rome, the birth certificate that established the EC.

EC-92 was officially launched in 1985, when the EC Commission published a white paper called "Completing the Internal Market." However, as the name implies, this was far from the start of Europe's long trek toward a single European economy. By the time EC-92 becomes a fait accompli, Europeans will be able to look back more than 40 years to their first major step toward integration. It was in 1951 that six countries (Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany) formed the European Coal & Steel Community (ECSC). Although it covered only two industrial sectors, ECSC nevertheless proved that it was possible to coordinate policy on a multinational level, independently of the founding national governments.

Buoyed by ECSC's success, leaders from the six countries started eyeing further economic integration. They achieved it in 1957, when they signed two treaties in Rome. One created the European Economic Community (EEC). The other established the European Atomic Energy Community (Euratom). Both the EEC and Euratom became effective Jan. 1, 1958. Together the three entities, ECSC, EEC, and Euratom, form the European Communities. But it's common practice now to simply refer to any or all as the European Community, or the EC. Over the years, the community has expanded to 12 member countries. In addition to the original six nations, EC members now include Denmark, Greece, Ireland, Portugal, Spain, and the U.K.

The goal of the Treaty of Rome signers was to form a customs union in which all obstacles to the free flow of goods, services, people, and capital among member countries would be re-

tive market for U.S. companies," he says. That goes for all U.S. companies, those that only export to Europe from the U.S. and those that produce within the EC through subsidiaries.

K. James O'Connor Jr., associate director of international trade for the Chemical Manufacturers Association (CMA), agrees. He says that a sense of optimism pervades the U.S. chemical industry as it awaits EC-92. Most U.S. chemical companies look upon EC-92 as an opportunity to tap a larger, more vigorous, and easier to penetrate European market.

But alongside the optimism linger those ever-present concerns. Will the new EC technical requirements and competition policy discriminate against U.S. and other non-EC companies? Despite repeated EC disclaimers, many wonder if EC leaders will weave new forms of protectionism into the fabric of EC-92 to create a "fortress Europe."

As Heckert points out, even now the doors to EC markets aren't completely open to imports. If EC-92 eliminates or substantially reduces present barriers to outside trade, U.S. chemical companies stand to gain, and gain big. But there's always the corollary. If things go the other way, they could suffer setbacks in the EC market.

There's much for the U.S. chemical industry to lose. Two-way chemical trade between the U.S. and the EC hit a record $17.2 billion last year. The U.S. exported $8.37 billion worth of chemicals to the 12-nation community in 1988, a hefty 26% of total chemical exports. That volume makes the EC by far the largest U.S. chemical export market.

Conversely, the EC ships more chemicals to the U.S. than any other trading bloc. Last year, the U.S. imported $8.85 billion in chemicals from the EC, a staggering 45% of total chemical imports.

But despite their size U.S. chemical exports to the EC belie the vast potential that awaits U.S. chemical companies there. Last year, total chemical sales in the EC hit $311 billion, according to the European Council of Chemical Manufacturers' Federations (CEFIC). That's 29% greater than the $241 billion in U.S. shipments of chemicals and allied products in 1988.

Because each of their national markets are relatively small, the EC chemical companies that generated those sales are heavily export oriented. Last year, their chemical exports hit $135 billion, more than four times what the U.S. shipped abroad. About 60%, or $79 billion, of those exports was intra-EC trade; that is, they were shipped by one EC country to other EC countries. The $8.37 billion in chemicals that the U.S. ships to the EC pales by comparison.

For large multinational companies such as Dow Chemical and Du Pont, which have had subsidiaries producing within the EC for years, the opportunities and challenges that EC-92 present are fairly clear. Because they receive "national treatment" as EC companies, they will fare the same as "European" chemical companies under EC-92. They should be able to rationalize production and increase their efficiencies the same as their European counterparts. Their costs of doing business in a single market with uniform regulations, even their R&D costs, should drop significantly.

For smaller U.S. chemical companies, however, the future under EC-92 is less clear. If they haven't done moved. In addition, all tariffs on intra-EEC shipments would be eliminated and a common external tariff established against noncommunity imports. Handling the internal and external tariffs proved far easier than solving the other problems. Industrial tariffs among the six member countries were removed and a common external tariff established in 1968.

Although the EC is a customs union in name, many nontariff barriers and other roadblocks still hamper the free flow of goods and services among the member countries. In fact, during the early 1980s, as economic stagnation gripped Europe, the ranks of unemployed workers swelled. European industries found it more difficult to compete against imports. As a result, EC member countries were pressured into erecting even higher trade barriers. These barriers impeded not only imports from third countries but from fellow members as well.

Faced with this Eurosclerosis, member governments realized that more, not less, cooperation was the key to increasing the efficiency and competitiveness of Europe's flagging industries. In 1982, the European Council stamped "priority" on the task of completing the internal market. The white paper published in 1985 listed all the measures still needed to complete the internal EC market.

The white paper is a very detailed document. It contains about 300 measures, or directives, designed to remove all physical, technical, and fiscal barriers to trade. More have been added since then. And it sets down a detailed timetable for implementing them. The deadline: Dec. 31, 1992.

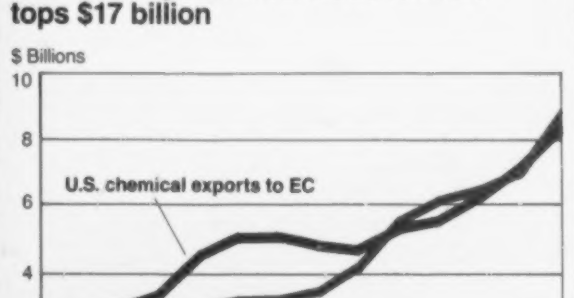
But the white paper would be just another piece of paper without the Single European Act. This act, which became effective in 1987, changes the voting procedures set forth in the Treaty of Rome. Instead of requiring a unanimous vote of the council, the act makes it possible to adopt many of the measures required for EC-92 by majority vote. About two thirds of the internal market directives listed in the white paper are subject to majority, rather than unanimous, vote. The primary exceptions concern taxes, professional qualifications, and employee rights.

Another important step toward EC-92 was the 1979 Cassis de Dijon case. In this case, the European Court of Justice said the commission has authority to overrule discriminatory import restrictions that individual member states impose on products made and marketed elsewhere in the EC. But without the Single European Act, EC-92 and its promise of a unified EC market probably would remain a dream. With it, the prospects for EC-92 are good.

so already, some of these companies will be looking to establish a production base within the EC through mergers and acquisitions. It's no coincidence that, since 1985, when EC-92 first took wing, the book value of direct U.S. chemical investment in the EC has soared. According to the Department of Commerce, U.S. chemical investment in the EC was $7.8 billion at the end of 1985. By the end of last year, it had rocketed to $14.4 billion.

But if a small U.S. company cannot, or will not, commit capital to establish a presence in the EC, the concerns about EC-92 are very real. These companies believe that the only way that they can benefit from the resurgent economy that EC-92 promises is to receive equal treatment along with their European competitors. And they fear that there may be as many pitfalls as promises as the EC blends 12 policies into one in such areas as technical standards, product testing and certification, competition policy, trade policy, and others.

U.S. two-way chemical trade with EC tops $17 billion



Source: Department of Commerce

For them, one overriding fact stands out. EC-92 was designed by Europeans to help Europeans. As EC-92 permits European chemical companies to become leaner and meaner, they likely will become even more formidable world-class competitors than they already are. They will be the ones with the inside track to a bigger share of a bigger EC market. And they will loom ever larger in U.S. and other world markets as well.

Like most others in the chemical industry who are playing an active role in monitoring EC-92, Richard M. Patterson feels good about the U.S. chemical industry's prospects after EC-92. Patterson, government relations manager for Dow Chemical U.S.A., says one of his primary goals is to see that the two-way U.S.-EC chemical trade continues to grow. If the U.S. and the EC work together, he is positive that it will increase. "It's in our mutual best interests to cooperate," says Patterson. "They [the EC] won't shoot themselves in the foot."

Nevertheless, he concedes that, for some U.S. chemical companies, there could be problems ahead as the EC completes its internal market. What's more, those problems will differ from company to company. How a U.S. company with heavy investment and plant capacity in Europe fares may be completely different from a company that exports to Europe only from its U.S. plants.

Dow, of course, is watching EC-92 from both perspectives. With its plants in West Germany, the Netherlands, Spain, Italy, and Portugal, it has been a major factor on the European chemical scene for a long time. Dow Europe is, essentially, a European company.

The entire panoply of developments coming out in EC directives will have an impact on Dow Europe, says Patterson. And he thinks that the changes that will come with EC-92 will give Dow Europe significant advantages. For instance, the savings in some activities such as sales and transportation could add $40 million to $50 million per year to Dow Europe's bottom line. Why? Because, when the EC market becomes unified, "you're talking one product for all of the EC instead of several. You're talking uniform shipping documents and uniform taxes," says Patterson.

Du Pont is another large U.S. multinational with a long and large legacy on the European chemical scene. Its European sales last year (including those of Conoco) were $9.5 billion, about 25% of total consolidated sales. Nancie Schalk Johnson, the company's manager for international trade and investment, is enthusiastic about EC-92's impact on Du Pont's European operations. For any product line that the company sells in Europe, she estimates that the potential is 5% greater with EC-92 than it would be without it. "A half billion dollars is not bad just for improved efficiency in the market," Johnson proclaims.

For some Du Pont products, the savings could be even greater. The company, for instance, makes medical x-ray film both in the U.S. and in Europe to serve both areas. It uses identical technologies, ingredients, and similar economies of scale in both locations. But Johnson estimates that, without EC-92, total costs in Europe are 40% higher than in the U.S.

Even as an exporter, says Dow's Patterson, Dow U.S.A. probably will benefit from EC-92, not only from the uniformity that it will bring, but also because of the new markets that are expected to develop as the EC economy grows. There is one caveat to that outlook, however, and that is the safety, health, and environmental standards that are being developed as part of the EC-92 program. If they have an anti-U.S. bias to them, then all bets are off. U.S. chemical exports to the EC could be hurt, and hurt badly.

Karen M. El-Chaar, international affairs analyst for the international gas division of Air Products & Chemicals, is also cautious. She says that small and mid-sized U.S. exporters are not so well positioned as the multinationals to cash in on EC-92. As a result, they are more anxious about its potential negative impact.

A leaner and meaner Europe, says El-Chaar, will put pressure on all U.S. businesses, not just those that trade with Europe. But for those who export to the EC in competition with European companies, the pressure will be particularly severe. To expand or even retain market share in an integrated EC, she says that the most critical choice facing small and mid-sized U.S. exporters is the route they will use to move their products into the EC market. Direct investment within the EC is one obvious choice. It also is one that many larger U.S. chemical companies have chosen.

Du Pont photo

Heckert: larger, more affluent, more integrated market

But companies that don't opt for direct investment must make other choices. If they want to continue exporting, they need to evaluate exporting directly or through agents or distributors. Aside from exporting, they also may want to consider licensing, franchising, technical agreements, and coproduction agreements. Such agreements help U.S. companies reduce risk by using the capital of their European partners. But they also have less control over their technology and more anemic profits.

Nothing about EC-92 concerns U.S. chemical companies more than the community's attempt to streamline its process for setting standards and to harmonize the many different national standards that now exist. Secretary of Commerce Robert A. Mosbacher made this clear when he said, "The issue of how standards will be set and what they will be is a top concern of the American business community."

About half of the EC directives on EC-92 deal with standards. In its recent study on the impact of EC-92 on the U.S., the International Trade Commission (ITC) pinpoints standards as one potential trouble spot for the U.S. chemical industry. John J. Gersic, head of ITC's chemicals section and a coleader of its EC-92 study project, says the number of products that may be affected is "potentially tremendous." Pesticides, fertilizers, cosmetics, and detergents are among those products.

The EC's attempt to harmonize its standards could turn out to be a double-edged sword. On the surface, greater harmonization of its many diverse national standards are expected to benefit U.S. companies. U.S. firms can produce a single product that they can market in all 12 EC countries, rather than modify their product for each individual market. The cost savings could be tremendous.

But potential problems lay beneath that surface. In a recent report on EC standards, the U.S. Chamber of Commerce raised these questions:

- Will the new harmonized EC standards aid or impede U.S. access to the European market?
- Will U.S. business, as a result of harmonization, have to meet EC standards that exceed those that now exist?
- Will U.S. industries have a voice in the EC standards-setting process?
- Will U.S. standards become increasingly isolated as the EC adopts its own standards?
- Will the EC's new testing and certification procedures amount to de facto barriers to U.S. products?

As yet, there are no clear-cut answers to these questions. It's no secret, however, that standards have been used to block otherwise competitive imports from entering a national market. The idea behind EC's standards harmonization effort is to make it easier for one member country to trade with other members. But the standards that the EC adopts could lower—or raise—barriers to imports from the rest of the world. It all depends on how the EC handles the details on standards, testing, and certification.

Under the EC's "new approach," the EC Commission will issue directives that specify very brief mandatory characteristics for groups of products that are considered risks to safety, health, and the environment. These are the so-called SHE directives and they are the ones that concern the U.S. chemical industry the most. To move freely throughout the EC, products in these specific groups must meet the directive's "essential requirements," as the EC calls them.

Meanwhile, two other standards approaches will be set up for the thousands of other products that will not be regulated by the essential requirements directives. For some, the community's "mutual recognition" concept comes into play. Under mutual recognition, if a product is certified as meeting a standard in one EC country, it can be marketed in any EC country. Others will be covered by product standards that will be established voluntarily throughout the EC.

Nothing about EC-92 standards irks U.S. chemical industry trade officials more than their inability to participate in EC standards-making procedures. U.S. firms with subsidiaries in Europe can take part through the various national standards groups that are associated with EC-wide standards organizations such as the Comité Européen de Normalisation (CEN). CEN will develop the detailed technical specifications for many of the "essential requirements" directives.

Companies that are not inside EC, however, "are out in the cold," says Stephen Cooney, director of international development and finance for the National Association of Manufacturers (NAM). The EC stresses that draft standards are always circulated to a U.S. standards group, usually the American National Standards Institute (ANSI) before they are finally adopted. But Cooney says that by then, it's already too late for U.S. companies to suggest changes. Chemical company executives couldn't agree more. This factor alone probably accounts for much of the direct investment that U.S. chemical companies have made in the EC.

In fairness, the EC is trying hard to improve outsider access to its standards-setting procedures. This was confirmed in a joint statement by Commerce Secretary Mosbacher and EC Internal Market Commissioner Martin Bangemann earlier this year. The statement also confirmed that the EC would attempt to develop international, rather than EC-only, standards.

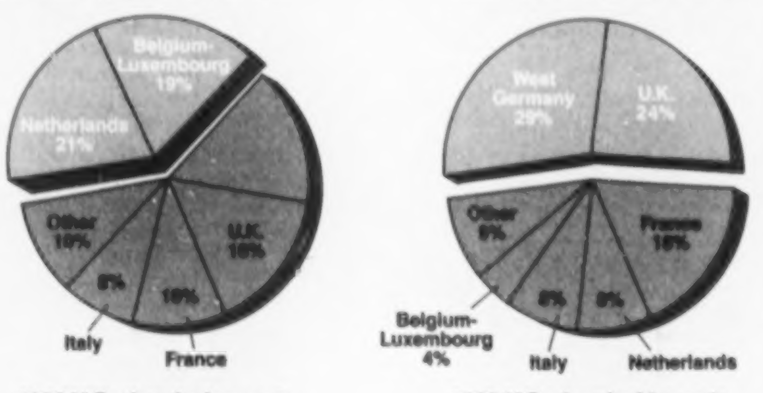
ANSI has suggested that a representative of the international standards bodies be allowed to attend technical meetings of the EC standards associations. This proposal has wide international support, and community officials seem favorably inclined toward it. Meanwhile, a bill in Congress would give $250,000 to the National Institute of Standards & Technology (NIST) for a pilot project to help countries draft standards that are beneficial to U.S. producers and products.

Even after a standard emerges that looks good to U.S. companies, they still have to thread their way through testing and certification procedures. "This could be the 'Achilles' heel' of the EC standards harmonization process," says Michaela D. Platzer, EC-92 program director for the Chamber of Commerce and coauthor of its report on EC standards.

Many unanswered questions remain, says Platzer. What laboratory testing protocols will be accepted by the EC? Will U.S. testing laboratories be accredited?

Benelux tops EC markets for U.S. chemical exports . . .

. . . while West Germany, U.K. export most to U.S.



1988 U.S. chemical exports to EC = $8.37 billion

1988 U.S. chemical imports from EC = $8.85 billion

Source: Department of Commerce

Will a company's own declaration of conformity be as creditable if it comes from a U.S. company as one that comes from a European company? There are no answers yet.

NAM's Cooney doesn't believe that the EC intends to use EC-wide standards as a barrier to trade with the rest of the world. Many in the chemical industry who have followed the standards issue agree. They warn against putting too much emphasis on the negative aspects of EC standards harmonization. The alternative, they point out, is for the EC to generate a completely new set of "EC standards" that would differ from both U.S. and international standards. That would force U.S. companies to produce products to three different sets of standards. The EC, says Dow's Patterson, is becoming much more aware of the need to harmonize EC and U.S. standards.

But despite the EC's best intentions, says Cooney, the pressures of time could limit its genuine efforts to achieve a truly international consensus. It takes about seven years to produce the typical international standard. The EC is aiming for a two-year turnaround on new standards proposals.

And there's always the possibility that some companies in some countries may try to manipulate standards to maintain or increase their market share. To make sure that nothing falls between the cracks, CMA and the Synthetic Organic Chemical Manufacturers Association (SOCMA) have developed "watch lists" of EC directives that they consider particularly important to U.S. chemical companies. Most of them concern standards, especially the SHE—safety, health, and environmental—directives.

Almost 80 EC directives are on the chemical industry watch lists, but the lists, says Patterson, are "moving targets." Each directive has been assigned to a company, which will analyze it and estimate its potential impact on the industry.

Each directive on the watch list also has been assigned an arbitrary "interest score" or number indicating how much interest the industry has in that particular directive. The higher the number, the greater the interest. All of the directives on the watch list have some potential impact on U.S. chemical companies. Otherwise, they wouldn't be on the list. However, those with the greatest interest among chemical companies include:

- L-90—good laboratory practices (nonclinical testing of chemicals).
- L-94—protection of workers by banning certain chemical agents and activities.
- C-34—extraction solvents.

The L and C numbers refer to identification numbers used by the Department of Commerce to track EC-92 developments as they occur. The department's International Trade Administration has set up a group—Single Internal Market Information Service (SIMIS)—specifically for that purpose.

SIMIS compiles all of the directives and initiatives that the EC has approved or is considering to complete its internal market and assigns them an identification number. L documents are directives, recommendations, and decisions that already have been approved by the member states and now are binding. C documents list those that still are being considered. These proposals are not binding yet, but their intention is clear. A third section in the SIMIS list covers regulations that the EC is committed to proposing, but for which no printed version exists. The SIMIS list now contains almost 390 directives and proposals.

The U.S. chemical industry is cautiously optimistic that the standards issue will be resolved satisfactorily for both the EC and the U.S. Too much two-way trade is at stake. The EC, says Patterson, has become much more aware of the need to harmonize U.S. and community standards. CMA says the General Agreement on Tariffs & Trade (GATT) standards code provides a sound basis for quickly resolving potential problems as the EC standards-setting process continues.

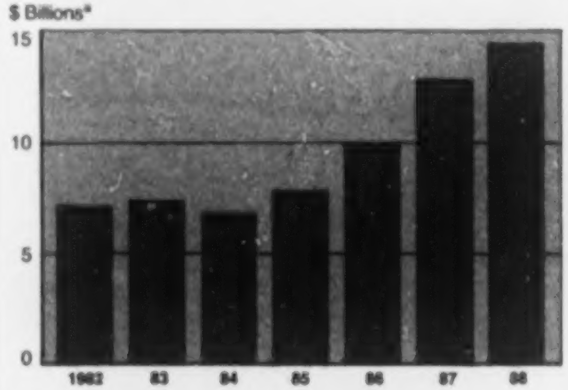
Although the standards issue looms head and shoulders above all others for the U.S. chemical industry, it is far from being the only one. How the EC intends to handle foreign direct investment and intellectual property rights are high on the list of chemical industry concerns. There is nothing in the EC directives, from government procurement, finances, customs controls, and transportation, to tax revision and competition policy, that won't affect U.S. chemical business in the EC.

None will bear watching more closely than the relationship between EC-92 and the Uruguay round of multilateral trade negotiations, now nearing completion at GATT in Geneva. U.S. Trade Representative Hills says that the very health of the entire global trading system will be determined by two events—EC-92 and the Uruguay round.

The U.S. chemical industry is a global industry. Any changes in trade policy—by anyone, anywhere—can help to shape its international business. Consequently, the industry has a lot riding on the outcome of the Uruguay round.

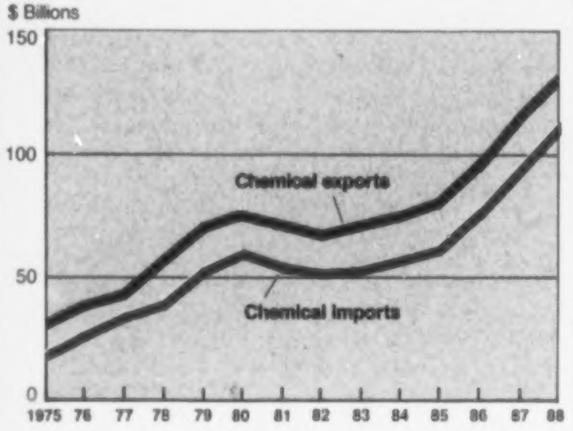
While the EC is engineering its EC-92 program, it also is a major player at the GATT trade negotiating

U.S. chemical industry's investment in EC has doubled since 1982



a Book value at year's end. **Source:** Department of Commerce

EC has large surplus in its chemical trade



Sources: Organization for Economic Cooperation & Development, European Community

table. U.S. chemical industry leaders, along with everyone else, wonder what impact EC-92 may have on those trade talks. EC officials no doubt will abide by its existing GATT obligations. But, for some areas such as intellectual property, foreign investment, and services, there are no GATT rules. These are still being negotiated in the Uruguay round. The question that looms large for the U.S. chemical industry is whether the Uruguay round will help to shape the outcome of EC-92 in these areas, or vice versa. The trade committees at CMA and SOCMA are watching the linkages between EC-92 and the Uruguay round closely.

Some internal EC policies and directives related to EC-92 may already be in place before negotiators reach their final decisions on these same issues at the GATT talks. If so, the EC may want to use them as bargaining chips in the Uruguay round. That way they can claim credit for the steps they have taken to liberalize the EC market, without having to negotiate them away in the trade talks.

Conversely, GATT negotiators are striving to come up with new international rules in areas not already covered by GATT. Foreign investment and intellectual property rights, as well as agricultural and services trade are prime examples. However, if the Uruguay round doesn't yield agreements on these areas, U.S. chemical industry trade experts wonder what the EC will do.

EC officials have said that they will allow imports from non-EC countries to enter the EC on a "reciprocal" basis until new international rules are established. But reciprocity is not clearly defined.

The EC already has put reciprocity clauses into several proposed directives. But U.S. government and business leaders aren't happy about them. They fear that these provisions could discriminate against U.S. companies. U.S. government officials say that reciprocity is not consistent with the principle of national treatment that they prefer.

The EC recently has been easing up on its reciprocity stance. But the uncertainty about reciprocity, along with the uncertainty about the interplay between EC-92 initiatives and the Uruguay round, makes U.S. chemical trade officials nervous.

Proposals to change the EC's intellectual property rules probably will help EC industries, including its chemical industry, to protect their vital technology. They should benefit from greater recognition of EC-wide patents and from the new Community Patents Appeals Court.

U.S. exporters may not be so fortunate. Last month, for instance, deputy U.S. trade representative S. Linn Williams asked the EC to change a proposed directive that he thinks will deny patent coverage for some U.S. biotechnology products. The proposed directive may streamline EC patent coverage in biotechnology, but, Williams says, U.S. biotechnology patent holders could be hurt by it.

Air Products' El-Chaar cites local content laws as a possible sore spot. These laws require foreign-owned companies to buy a minimum percentage of their supplies from domestic sources. She says the EC Commission is considering local-content requirements that could push U.S. firms into investing in the EC simply to avoid the import restrictions that these rules impose.

Although neither CMA nor SOCMA has issued position papers yet, they and their members generally support the EC's attempt to unify its internal market. So far, CMA's trade officials say they see nothing in EC-92 that singles out the chemical industry for special treatment or that overtly discriminates against non-EC companies in any way.

But CMA and SOCMA aren't throwing caution to the wind, either. They will continue to maintain their "watch lists" and try to make changes in those EC directives that they think may harm U.S. chemical companies.

Du Pont's Johnson wonders if the U.S. chemical industry should greet EC-92 with "Europhoria" or "Europaranoia." Her answer: somewhere in between. And that's just about where the U.S. chemical industry's reaction lies.

"At the very least, things will not get worse under EC-92," says Du Pont's Heckert. At best, he adds, substantial gains are likely for internal EC growth and for growth in world trade.

Heckert also believes that concerns about EC-92 are overblown and could be counterproductive. U.S. companies that export to Europe or produce there should accept the fact that major, and perhaps irreversible, changes are taking place in that market, he says. His advice: Companies should focus on being as competitive as possible so that they can share the benefits of a truly integrated EC market.

At the same time, Heckert warns both companies and U.S. government officials to pay attention to and react quickly to any EC-92 developments that aren't in their own best interests. He doesn't think that EC-92 will create a "fortress Europe." But he believes that, if the EC chooses protectionism, the U.S. should retaliate.

Few in the chemical industry would disagree with him. ☐

A1250-1

Chemical company earnings fall in third quarter; first decline in three and a half years Page 8

NOVEMBER 13, 1989

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National Chemistry Week

Variety of activities aims to improve public understanding of chemistry Page 26

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CHEMICAL & ENGINEERING NEWS

NOVEMBER 13, 1989

News of the Week

- **OSHA to tighten regulation of chemical plants, in wake of explosion and fire at Phillips 66 polyethylene complex in Pasadena, Tex. Page 4**
- **Debate sharpens over how to deal with radioactive waste accumulating at U.S. nuclear power plants. Page 5**
- **Chemical executives attending CMA's annual conference last week in Washington, D.C., expect benefits for their firms from EC-92. Page 5**
- **A. H. Robins' Dalkon Shield case, one of the largest product liability cases, is finally nearing an end. Page 6**
- **New instrumentation being developed by Applied Biosystems may speed the human genome project. Page 6**

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Chemical company earnings fell in the third quarter, marking the first year-to-year decline since fourth-quarter 1985. **Page 8**

Shell International Chemical is looking for new markets for its C_5 olefin-based acids and derivatives. **Page 13**

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Pesticide standards, food safety measures focus of proposals offered by President, Congress. **Page 15**

1990 R&D budgets may stagnate due to across-the-board cuts imposed by Bush. **Page 17**

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Superconductor research achieves new milestones in work on single crystals and thin films of yttrium-barium-copper oxide. **Page 22**

Inexpensive, reliable eye-safe lidar developed by researchers at Georgia Institute of Technology. **Page 23**

Catenane synthesized in one-step reaction in 70% yield by chemists at Sheffield University, England. **Page 24**

Books

Sierra Club book on global warming strives to give full-spectrum view of the "greenhouse" debate. **Page 39**

Cover: National Chemistry Week display outside Chicago Academy of Sciences. Photo by C&EN's Ward Worthy

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National Chemistry Week

Solutions for the Future

Cover Story

ACS's National Chemistry Week, aimed at impressing on the public and particularly on the young chemistry's essential role, was marked by hundreds of projects in locations across the nation. Page 26

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LETTERS

CHEMICAL SAFETY

Formic acid explosion

SIR: A storeman recently lost an eye when an E. Merck of Darmstadt, West Germany, 1-L bottle of 98 to 100% formic acid exploded as he lifted it off the shelf in the main store of this chemistry school. He was not wearing safety glasses. Concentrated formic acid slowly decomposes to carbon monoxide and water upon prolonged storage, and the gas pressure can be sufficient to rupture sealed glass containers. It happens that none of the academic or technical staff members of the school were aware of this hazard. The first descriptions in the general safety literature appear to have been in the second edition of L. Bretherick's "Handbook of Reactive Chemical Hazards" [Butterworths, London, page 298 (1979)] and the third edition of "Hazards in the Chemical Laboratory" [Royal Society of Chemistry, page 339 (1981)].

Merck recognized the problem some years ago, and in 1984 changed the ordinary white screw cap to a black cap incorporating a degassing valve. The significance of the change was, however, not widely communicated to their customers in this region. The bottle that exploded here was the old type with a white cap. The purpose of this note is to advise chemists to check their stocks of 98 to 100% formic acid. Any bottle from Merck or other suppliers that does not have a pressure relief valve in the cap should be made safe by gently unscrewing the cap. This should be done only while wearing a face shield, goggles, and heavy-duty gloves and overalls, with another person standing by in the event of an explosion. Such old stock should also be used soon. Our experience reinforces the desirability of wearing safety glasses whenever chemicals are being handled.

A. V. Robertson
School of Chemistry
University of Sydney, Australia

Editor's note: E. Merck of Darmstadt, West Germany, is not affiliated with Merck, Rahway, N.J., which does not supply reagent chemicals, including formic acid.

Upgrading science

SIR: Education in the physical/biological sciences and mathematics sectors can be easily (but with some bloodletting) upgraded at the precollege level as follows.

Eliminate tenure completely and adopt objective methods of performance review used in industry to weed out the deadwood and reward and attract solid professional talent to primary and secondary school education. Industry no longer has any guarantee of permanent professional employment. This died in the early 1960s. If you can't produce, out you go—no more good-old-boy system to protect you.

Start attracting enthusiastic, talented people by paying competitive salaries. If this requires a surtax at the state level, so be it. The time for hand-wringing and bemoaning poor quality technical education must come to an end now! Let's get our best industrial people together into a task force and get the mechanisms into place that will start the upgrading of our nation's science and math programs within the next year.

Seymour Broad
Cincinnati

Space exploration benefits

SIR: I read with utter disbelief the letter of Robert Kofahl (C&EN, Sept. 4, page 69) regarding the "uselessness" of space exploration. Such a contemptuous opinion from a layperson would not be as surprising, but from a presumably scientifically trained person, it is inexcusable.

That "hoisting people to the moon" in silly "escapades" has no military or economic value for the nation can be disproven in a multitude of discussions. Kofahl has obviously never taken a course in the history of science nor does he understand the nature of discovery. Many great discoveries and accomplishments result from striving for what we only think is impossible. Through the ages, people's curiosity and desire for knowledge have advanced us from the days of Galileo to the computer age. Develop the same technology by staying in "inner space"? The fact is that one does not stand up and say, "Let us discover the new realm of topography and meteorology to improve the world's food supply today"; or, "Gee, let's invent some new ceramics to withstand space conditions and temperatures of reentry to Earth's atmosphere"; or, "Let's dream up novel ways to use and alter computer technologies" (recent Voyager results being a case in point).

So many technologies could not have even been thought of without the perspective of space, or without the goal to strive for. Many thousands of scientists and engineers, tirelessly focused on a single grand goal, accomplished more in the moon mission than in any other

Chemical Earnings Turn Down In Third Quarter

William J. Storck,
C&EN Northeast News Bureau

After three and a half years of solid growth in earnings, the chemical industry has finally turned down. The third-quarter results from chemical firms represent the first year-to-year decline in quarterly earnings since the fourth quarter of 1985. Combining to halt the increases were lower selling prices and declining demand for many petrochemical derivatives.

Oil earnings and chemical earnings at energy companies also fell, but earnings at diversified companies that produce chemicals and at pharmaceutical firms generally continued to increase.

In the second quarter, earnings from chemical companies ended their long string of double-digit increases. Still, they managed to post a modest gain. Now, however, earnings have sunk into a double-digit decline.

The slide in earnings has been caused at most companies by falling demand and prices. This is especially true at petrochemical operations, where the decrease in feedstock costs has not been taking place as rapidly as the decrease in selling prices of polymer products. For instance, Du Pont says that its polymers segment reported lower earnings in the third quarter, reflecting the impact of softening demand and lower selling prices on ethylene-based products for the packaging and industrial polymer markets.

And sales of Dow Chemical's plastics business slipped almost 1% for the quarter. Polyethylene prices, according to the company, were hit by summer inventory corrections and increased ethylene availability.

Chemical industry leaders for the third quarter . . .

Sales

Rank 1989		$ Millions	Rank 1988
1	Dow Chemical	$4250.0	1
2	Union Carbide	2141.0	2
3	Monsanto	2061.0	3
4	W. R. Grace	1487.5	4
5	American Cyanamid	1140.8	5
6	Hercules	787.4	8
7	Air Products	668.6	9
8	Arco Chemical	632.0	7
9	Rohm & Haas	623.0	10
10	Ethyl	613.7	13

Earnings[a]

	$ Millions	Rank 1988
Dow Chemical	$589.0	1
Union Carbide	139.0	2
Monsanto	126.0	4
Arco Chemical	94.0	3
American Cyanamid	64.5	7
Ethyl	54.8	11
Air Products	51.0	9
Georgia Gulf	46.1	8
Grace	45.5	12
B. F. Goodrich	39.1	6

Profitability

	Earnings as % of sales	Rank 1988
Georgia Gulf	18.3%	2
International Flavors	15.8	5
Arco Chemical	14.9	3
Dow Chemical	13.9	6
Great Lakes Chemical	13.8	1
Vista Chemical	12.8	4
Loctite	12.6	10
Nalco Chemical	12.0	13
Betz Laboratories	11.3	11
Aristech	9.5	7

. . . and for first nine months of 1989

Sales

Rank 1989		$ Millions	Rank 1988
1	Dow Chemical	$13,336.0	1
2	Monsanto	6,674.0	2
3	Union Carbide	6,659.0	3
4	W. R. Grace	4,395.4	4
5	American Cyanamid	3,671.7	5
6	Hercules	2,318.3	7
7	Arco Chemical	2,057.0	8
8	Quantum Chemical	2,044.3	6
9	Rohm & Haas	2,037.7	9
10	Air Products	2,001.3	10

Earnings[a]

	$ Millions	Rank 1988
Dow Chemical	$2060.0	1
Monsanto	589.0	2
Union Carbide	526.0	3
Arco Chemical	330.0	4
American Cyanamid	263.9	6
Air Products	161.0	9
Ethyl	156.9	10
Rohm & Haas	155.0	7
Georgia Gulf	150.7	11
B. F. Goodrich	143.1	8

Profitability

	Earnings as % of sales	Rank 1988
Georgia Gulf	17.5%	3
International Flavors	16.8	6
Great Lakes Chemical	16.2	2
Arco Chemical	16.0	1
Dow Chemical	15.4	7
Vista Chemical	15.1	4
Loctite	12.7	9
Nalco Chemical	11.1	11
Betz Laboratories	10.9	9
Monsanto	8.8	18
Ethyl	8.8	15

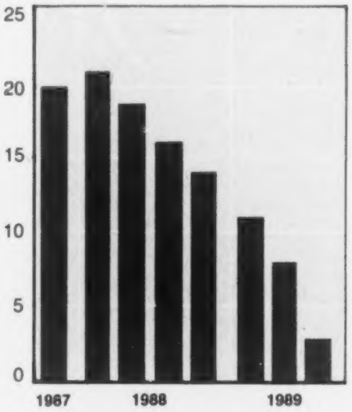
Note: Based on 30 chemical companies listed on page 10. [a] After taxes.

Chemical industry 1989 third-quarter results

- Sales increased 3%
- Earnings fell 15%
- Profit margins at 8.1%
- Production rose 4.9%
- Prices moved up 3.8%

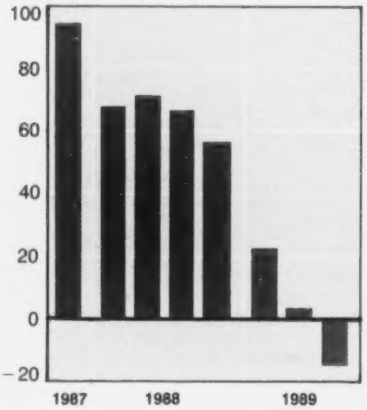
Sales

% change from year-earlier quarter



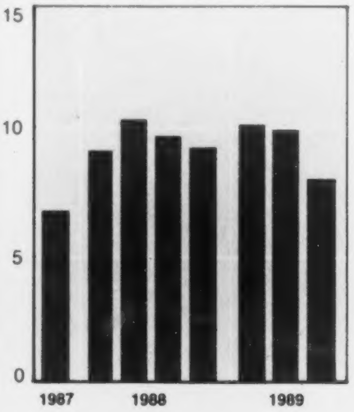
Earnings

% change from year-earlier quarter



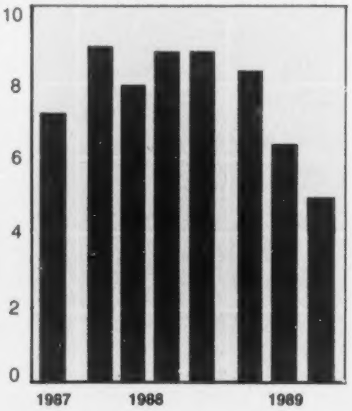
Profit margins

After-tax earnings as % of sales



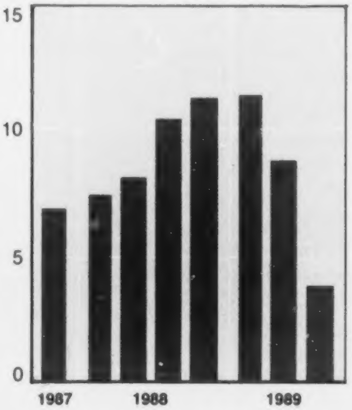
Production

% change from year-earlier quarter



Prices

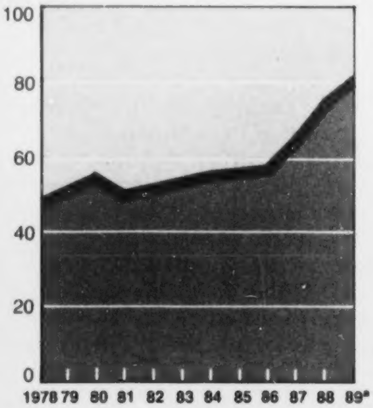
% change from year-earlier quarter



Sales in 1989 will rise about 6% while earnings will be flat, lowering profit margins to about 9.2%

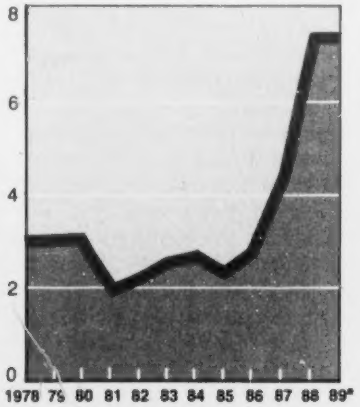
Annual sales

$ Billions



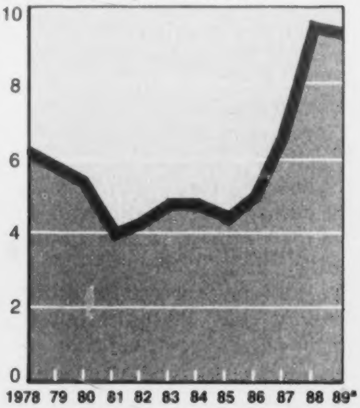
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit margin data are based on combined results of 30 companies listed on page 10. a C&EN estimates.

Chemical earnings fall 15% in third quarter on modest sales increase

	THIRD-QUARTER 1989						NINE-MONTHS 1988			
	Sales	Earnings[a]	Change from 1988		Profit margin[b]		Sales	Earnings[a]	Change from 1988	
	($ millions)		Sales	Earnings	1989	1988	($ millions)		Sales	Earnings
Air Products[c]	$ 668.6	$ 51.0	7%	1%	7.6%	8.1%	$ 2,001.3	$ 161.0	8%	2%
American Cyanamid[c]	1,140.8	64.5	4	1	5.7	5.9	3,671.7	263.9	5	9
Arco Chemical[c]	632.0	94.0	−9	−25	14.9	18.1	2,057.0	330.0	5	−8
Aristech	230.4	21.9	−17	−47	9.5	15.0	773.8	67.0	−4	−48
Betz Laboratories	133.4	15.1	16	18	11.3	11.1	388.2	42.4	17	18
Cabot[c]	445.4	−5.1	11	def	def	1.0	1,456.9	33.5	13	−14
Chemed	153.3	7.9	4	25	5.1	4.3	446.2	20.4	26	21
Crompton & Knowles	87.9	5.8	10	47	6.6	4.9	270.7	18.5	33	46
Dow Chemical[c]	4,250.0	589.0	2	−7	13.9	15.2	13,336.0	2060.0	8	16
Ethyl[c]	613.7	54.8	18	19	8.9	8.8	1,790.0	156.9	18	12
First Mississippi	102.5	0.9	25	−80	0.9	5.5	357.7	6.9	52	−62
H. B. Fuller	189.9	3.8	7	−35	2.0	3.3	563.8	10.6	12	−35
Georgia Gulf	251.2	46.1	−10	−13	18.3	19.0	861.3	150.7	11	8
B. F. Goodrich[c]	601.3	39.1	−3	−43	6.5	11.1	1,846.0	143.1	7	−13
W. R. Grace[c]	1,487.5	45.5	7	1	3.1	3.3	4,395.4	120.4	6	−8
Great Lakes Chemical	228.7	31.7	65	18	13.8	19.3	566.1	91.5	36	21
Hercules[c]	787.4	30.5	15	−5	3.9	4.7	2,318.3	108.3	13	0
International Flavors	216.9	34.2	8	11	15.8	15.4	680.9	114.2	3	8
International Minerals	311.4	7.5	43	−34	2.4	5.2	835.7	59.9	18	−6
Loctite	114.9	14.4	8	21	12.6	11.2	352.2	44.7	8	26
Lubrizol	274.7	21.4	3	−37	7.8	12.8	947.3	78.1	12	−2
Monsanto[c]	2,061.0	126.0	2	7	6.1	5.8	6,674.0	589.0	4	8
Nalco Chemical	270.0	32.5	9	21	12.0	10.8	787.6	87.3	8	12
Olin[c]	580.0	24.0	7	26	4.1	3.5	1,909.0	93.0	13	21
Petrolite	71.9	3.3	0	31	4.6	3.5	216.2	8.6	−4	−21
Quantum Chemical[c]	557.7	20.3	−23	−79	3.6	13.1	2,044.3	137.7	−3	−49
Rohm & Haas[c]	623.0	32.6	1	−35	5.2	8.0	2,037.7	155.0	5	−17
Union Carbide[c]	2,141.0	139.0	2	−35	6.5	10.1	6,659.0	526.0	8	5
Vista Chemical	186.9	23.8	−5	−28	12.8	16.8	587.7	88.7	−2	−11
Witco[c]	395.0	20.5	−2	2	5.2	5.0	1,208.0	64.0	1	2
Total 15 larger companies	**$16,984.5**	**$1325.7**	**2%**	**−16%**	**7.8%**	**9.5%**	**$53,404.5**	**$4941.8**	**7%**	**4%**
Total 15 smaller companies	**$ 2,824.0**	**$ 270.2**	**8%**	**−11%**	**9.6%**	**11.7%**	**$ 8,635.4**	**$ 889.5**	**12%**	**−3%**
GRAND TOTAL	**$19,808.5**	**$1595.9**	**3%**	**−15%**	**8.1%**	**9.8%**	**$62,039.9**	**$5831.3**	**8%**	**3%**

a After-tax earnings from continuing operations, excluding significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales. c One of the 15 largest companies. def = deficit.

But, it says, demand remained strong for all of its specialty plastics.

Demand has fallen off in a number of markets important to the chemical industry. For instance, durable goods orders and shipments have slowed in the past few months. The number of new housing starts has declined in recent months, and fewer housing starts translates into lower demand for plastics and other chemicals used in the housing industry.

The auto market was artificially buoyed at the end of the model year by intensive incentive programs such as rebates to customers. However, as these programs ran out, the new model year has not begun with any great purchasing on the part of car buyers, thus cutting demand for chemical products in this sector.

In agriculture, another big sector of the chemical industry, demand is up somewhat, but it is still growing very slowly.

The gross economic numbers for the chemical industry still look fairly good on a year-to-year basis. Production of chemicals and allied products in the third quarter rose 5% over the same period last year. And prices for the same chemical category are up almost 4% over third-quarter 1988, according to government figures.

Basic chemicals also registered advances in the third quarter, with production up about 8% and prices almost 4% over third-quarter 1988. However, compared with the second quarter, although the output of basic chemicals is up a healthy 4%, prices slipped almost 3%.

Other factors that entered into the lower earnings for the quarter, according to the companies reporting, were negative foreign currency translations, downtimes for plant maintenance, and startup costs for new plants and expansions. One factor not mentioned by these companies is that they seem to be losing some of the efficiency that was built up in the mid-1980s when they cut work forces, streamlined plants, and generally made an intensive effort to cut costs.

In recent quarters, productivity

NINE-MONTHS 1988		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1988		Profit margin[b]	
1989	1988	Sales	Earnings	1989	1988
8.0%	8.6%	9%	4%	8.4%	8.8%
7.2	7.0	6	8	6.8	6.7
16.0	18.4	14	7	16.6	17.5
8.7	16.1	−2	−8	10.8	11.5
10.9	10.8	16	19	10.9	10.7
2.3	3.0	16	2	2.9	3.3
4.6	4.8	30	10	4.1	4.8
6.8	6.2	23	44	6.4	5.4
15.4	14.3	10	27	15.3	13.3
8.8	9.2	23	1	9.4	11.4
1.9	7.7	41	−42	2.9	7.0
1.9	3.2	13	−34	2.1	3.6
17.5	17.9	17	18	17.9	17.8
7.8	9.5	3	13	7.9	7.3
2.7	3.2	11	−12	2.9	3.7
16.2	18.2	29	27	16.8	17.0
4.7	5.3	10	−21	4.4	6.2
16.8	16.0	3	8	15.9	15.1
7.2	8.9	−8	−24	7.0	8.4
12.7	10.8	8	27	12.3	10.5
8.2	9.4	12	15	8.2	8.0
8.8	8.5	4	7	7.4	7.1
11.1	10.6	9	16	11.0	10.4
4.9	4.6	16	23	4.5	4.3
4.0	4.8	−5	−27	3.7	4.8
6.7	12.7	−9	−27	9.0	11.2
7.6	9.7	6	−12	7.5	9.1
7.9	8.1	10	42	8.5	6.5
15.1	16.5	0	0	15.7	15.7
5.3	5.2	1	1	5.1	5.1
9.3%	**9.5%**	**8%**	**13%**	**9.1%**	**8.6%**
10.3%	**11.9%**	**15%**	**11%**	**12.0%**	**12.3%**
9.4%	**9.8%**	**9%**	**13%**	**9.5%**	**9.1%**

growth in the chemical industry has been slipping and unit labor costs have been rising (C&EN, Sept. 4, page 11). In the second quarter, while these measures of productivity faltered for the chemical industry, they improved for the government's broad all-manufacturing category—a danger signal for the chemical economy. While complete figures aren't yet available, there is no indication that this situation changed in the third quarter.

Chemical companies have increased the size of their work forces considerably. The reductions in force that characterized the mid-1980s are long past. Some of this increase in hiring has been brought about, of course, by the need for more employees to handle the greater volume of production and of doing business.

However, chemical firms may well be getting "employee rich" again. According to Labor Department figures, between the end of the third quarter of 1988 and the third quarter of 1989, the chemicals and allied products industry added 21,000 employees, or about 2%, to its rolls. Industry employment has increased almost 7% since the decade-low year of 1986.

Another possible indication of the drop in productivity is the cost of selling the goods that the chemical industry makes. For a group of eight companies—American Cyanamid, Arco Chemical, Georgia Gulf, Great Lakes Chemical, Hercules, Monsanto, Olin, and Rohm & Haas—that break out such figures, the "cost of goods sold" or manufacturing costs—the largest cost component of a company's income statement— rose about 3.4% in the third quarter over the same period last year.

But an even bigger increase for these companies came in their selling, general, and administrative expense (SG&A). SG&A includes the cost of selling—advertising, salesmen's expenses and salaries, and other selling costs—and of administration of the company. This expense increased an average of 11% for the eight firms, while their sales rose an average of just 4%.

If these costs are increasing for companies throughout the industry and if demand and prices continue to falter, then earnings are going to continue to decline and they may decline rapidly.

Whatever the reasons, chemical industry earnings, while good by historic standards with most companies still potentially able to post record earnings for the year, were not good in the third quarter compared with the third quarter of last year.

Combined earnings from continuing operations, excluding significant nonrecurring and extraordinary items, for the 30 major U.S. chemical companies regularly surveyed by C&EN fell 15% in the quarter to just less than $1.60 billion. This decline came on a 3% increase in sales to $19.8 billion. As a result, the average profit margin for these companies fell to 8.1% from 9.8% in the third quarter of 1988. This is also the lowest average profit margin for the group since fourth-quarter 1987, when this profitability ratio stood at 6.9%.

The larger companies were outperformed by the smaller companies for the third quarter in all categories. Earnings for the 15 larger companies for the quarter totaled $1.33 billion, down 16% from the same period in 1988. Sales for this group increased 2% to about $17.0

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 23 oil and diversified companies, each with more than $200 million in annual chemical sales, plus 10 pharmaceutical companies.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Earnings slide at oil firms, but are mostly up at diversified and drug companies

	THIRD-QUARTER 1989						NINE-MONTHS 1989					
	Sales	Earnings[a]	Change from 1988		Profit margin[b]		Sales	Earnings[a]	Change from 1988		Profit margin[b]	
	($ millions)		Sales	Earnings	1989	1988	($ millions)		Sales	Earnings	1989	1988
OIL AND GAS COMPANIES												
American Petrofina	$ 711.9	$ 15.1	2%	−57%	2.1%	5.1%	$ 2,278.2	$ 105.7	16%	6%	4.6%	5.1%
Amoco	5,850.0	336.0	14	−39	5.7	10.7	17,885.0	1291.0	14	−24	7.2	10.8
Ashland	2,300.0	38.3	5	−58	1.7	4.1	6,239.8	76.8	2	−55	1.2	2.8
Chevron	8,000.0	417.0	11	−1	5.2	5.8	23,900.0	1134.0	9	−9	4.7	5.7
Exxon	23,657.0	1110.0	8	−9	4.7	5.6	69,512.0	3420.0	6	−12	4.9	5.9
Kerr-McGee	749.6	18.9	18	−33	2.5	4.4	2,288.2	87.9	14	29	3.8	3.4
Mobil	13,636.0	532.0	4	−4	3.9	4.2	41,689.0	1362.0	2	−14	3.3	3.9
Occidental Petroleum	4,826.0	34.0	−2	−69	0.7	2.2	15,019.0	194.0	6	−37	1.3	2.2
Shell Oil	5,869.0	340.0	0	−7	5.8	6.2	17,729.0	1141.0	4	15	6.4	5.8
Sun Co.	2,730.0	85.0	11	18	3.1	2.9	8,300.0	271.0	14	19	3.3	3.1
Texaco	8,356.0	305.0	−4	11	3.7	3.2	26,415.0	887.0	−1	24	3.4	2.7
Unocal	2,818.0	79.0	8	−19	2.8	3.7	8,532.0	286.0	14	28	3.4	3.0
DIVERSIFIED MANUFACTURERS												
Du Pont	8,589.0	547.0	9	19	6.4	5.9	26,541.0	1997.0	10	18	7.5	7.0
Tenneco	3,210.0	90.0	6	84	2.8	1.6	10,194.0	379.0	6	115	3.7	1.8
3M	2,994.0	307.0	5	4	10.3	10.3	9,036.0	952.0	5	8	10.5	10.3
Allied-Signal	2,827.0	121.0	−1	1	4.3	4.2	8,884.0	390.0	0	6	4.4	4.1
Borden	1,962.8	100.9	5	10	5.1	4.9	5,640.5	243.9	7	12	4.3	4.1
PPG Industries	1,360.1	106.7	0	−5	7.8	8.3	4,309.9	363.8	3	0	8.4	8.7
FMC	837.6	34.8	5	12	4.2	3.9	2,591.8	124.4	8	33	4.8	3.9
Engelhard	586.4	17.5	−5	32	3.0	2.2	1,776.7	47.0	7	15	2.6	2.5
Vulcan Materials	307.2	50.5	3	2	16.4	16.5	818.5	109.7	4	−1	13.4	14.1
Ferro Corp.	266.7	11.9	8	1	4.5	4.8	813.6	37.4	9	7	4.6	4.7
NL Industries	249.5	65.8	1	93	26.4	13.8	761.5	149.7	−1	47	19.7	13.2
PHARMACEUTICAL COMPANIES												
American Home Products	1,507.9	266.2	7	11	17.7	17.0	4,428.4	766.7	5	11	17.3	16.5
Baxter International	1,808.0	102.0	6	20	5.6	5.0	5,438.0	307.0	8	15	5.6	5.3
Bristol-Myers Squibb	2,319.6	410.7	6	16	17.7	16.2	6,828.9	1099.5	6	14	16.1	15.0
Merck	1,632.8	390.5	11	25	23.9	21.2	4,789.4	1127.5	9	25	23.5	20.4
Pfizer	1,438.5	217.5	4	0	15.1	15.7	1,508.4	594.0	0	−9	39.4	43.3
A. H. Robins	264.3	12.0	3	−50	4.5	9.3	678.4	31.1	2	−34	4.6	7.1
Roror Group	260.5	19.6	7	29	7.5	6.2	778.7	41.8	9	20	5.4	4.9
Schering-Plough	743.7	114.0	3	21	15.3	13.0	2,381.0	360.2	7	21	15.1	13.3
Upjohn	715.3	96.0	10	7	13.4	13.7	2,207.0	293.6	8	8	13.3	13.4
Warner Lambert	1,108.0	106.9	7	22	9.7	8.5	3,152.3	320.4	8	22	10.2	9.0

a After-tax earnings, excluding significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales.

billion. As a result, profit margins averaged 7.8%, down considerably from the 9.5% average in third quarter last year.

For the 15 smaller firms, earnings fell 11% to $270 million on a sales increase of 8% to $2.82 billion. Profitability for the group slipped to 9.6% from 11.7% in the year-earlier third quarter.

For the nine months, combined earnings for the 30 companies rose 3% to $5.83 billion on an 8% sales increase to $62.0 million. Profitability slipped to 9.4% from 9.8% in the first nine months last year.

The larger firms performed better than the smaller ones in terms of profits in the first nine months. Earnings at the 15 larger firms for this period rose 4% to $4.94 billion on sales up 7% to $53.4 billion. Profitability for the group declined slightly to 9.3% compared with 9.5% in last year's first nine months.

For the 15 smaller companies, nine-month earnings fell 3% to $890 million from the same period in 1988. Sales for the firms rose 12% to $8.64 billion. As a result, however, profitability, though still higher, had a much greater fall. Profit margins for these firms dropped to 10.3% in the first nine months this year from 11.9% in the year-earlier period.

Chemical companies came in last in earnings growth compared with other industry groups surveyed by C&EN. Twelve oil companies posted an earnings decline of 13% (compared with chemical companies' 15%) to a combined $3.31 billion on

Slipping product prices hurt chemical earnings at oil firms

Chemical earnings at major oil companies, like those at chemical firms, fell in the third quarter, but the decline was much greater for the oil producers. Combined chemical earnings for seven of these firms reporting such figures—Amoco, Chevron, Exxon, Mobil, Occidental, Shell, and Unocal—dropped 26% from the year-earlier period to $978 million. This brings the gain in chemical earnings for the first nine months of 1989 to only 4%, for a total of almost $3.60 billion.

As oil companies derive the bulk of their chemical earnings from petrochemicals, their results give a good indication of the health of the basic petrochemicals industry and the polymers business.

Practically all the oil companies complained that profit margins were sinking throughout the quarter as polymer prices fell faster than did costs of their raw materials such as ethylene and benzene. The decline in market prices for polymers was caused by an increasing weakening of demand and a subsequent building of supplies in the marketplace.

For instance, Amoco, whose chemical earnings fell 34% for the third quarter, said the decline was due primarily to shrinking commodity chemical margins as increased supply depressed prices. This was particularly true for polymers.

Mobil, which also recorded a 34% drop in earnings in the quarter, said the decline reflected lower polyethylene prices worldwide. However, Mobil pointed out that, despite the decline, earnings continued strong with good performance from ethylene glycol and the plastics fabricating business, particularly oriented polypropylene.

Occidental, with a 10% drop in chemical earnings for the quarter, stated that lower profit margins in petrochemicals were partly offset by increased volumes and margins in electrochemicals, specialty products, and agricultural chemicals.

EARNINGS ON CHEMICAL OPERATIONS

	Third quarter			Nine months		
$ Millions	1989	1988	% change	1989	1988	% change
Amoco	$120	$181	−34%	$402	$539	−25%
Chevron	78	112	−30	317	340	−7
Exxon	254	344	−26	954	966	−1
Mobil	125	188	−34	491	482	2
Occidental	254	283	−10	842	622	35
Shell	137	204	−33	546	480	14
Unocal	10	10	0	47	35	34
TOTAL	$978	$1322	−26%	$3599	$3464	4%

billion on 5% sales growth to $79.5 billion.

A group of 11 diversified and other firms that produce chemicals recorded an earnings increase of 14% to $1.45 billion—but largely on the strength of a 93% increase at NL Industries. And 10 firms in the higher-value-added and less cyclical drug industry had an average earnings gain of 15% to $1.74 billion on sales up 6% to $11.8 billion.

So midway through the fourth quarter, the question is: Are the third-quarter results a harbinger of things to come or are they simply an indication that the industry is returning to sustainable levels?

Dow certainly holds to the latter view. Enrique C. Falla, the company's chief financial officer, says, "In 1988 and early 1989, we experienced shortage conditions and unprecedented pricing and margins, particularly in our ethylene derivatives business. As product availability has improved globally, we are returning to sustainable margins in line with long-term goals."

And at Monsanto, which was the largest of the 15 chemical companies whose earnings did not decline in the third quarter, chairman Richard J. Mahoney says, "We will set new records for sales and earnings [for the year], and make good progress toward our 20% return on equity objective." □

Shell steps up efforts in specialty acids

Shell International Chemical Co. has launched a drive to find new applications for its C_5 olefin-based acids and derivatives. The company has just dedicated a $25 million specialty acids unit at Pernis, the Netherlands. The new plant, located next to the company's existing olefin acids unit, produces a range of specialty acids using the Koch process for preparing tertiary monocarboxylic acids in the presence of strong acid catalysts, under high carbon monoxide pressure and high temperatures. It is part of a major refurbishing effort to upgrade and expand the Pernis site.

Shell's existing facility produces mostly C_9, C_{10}, and C_{11} acids and derivatives. However, according to Shell marketers, demand is growing for C_5 to C_7 acids, to the point that a separate unit is needed. The capacity of the new plant is about 22 million lb per year. Principal product is pivalic acid—2,2-dimethyl propanoic acid. Moreover, the company is planning a kilogram-scale experimental unit at Pernis to help with market development of new Koch acids. Feedstock is the dicyclopentadiene separated from a C_5 fraction at Shell's nearby Moerdijk cracker.

According to Robert Taylor, head of fine chemicals business development, most of Shell's olefin acids go to five major markets: agrochemicals, pharmaceuticals, aroma chemicals, specialty polymers, and polymer additives. The company's focus on pivalic acid is part of its philosophy for fine chemicals—to concentrate on manufacturing family trees and highly differentiated processes.

Fine chemicals are, for Shell, about a $230 million to $240 million per year business. Besides the Koch acids facilities at Pernis, the company has a variety of fine chemicals operations throughout Europe. For example, it carries out olefin cyclization and metathesis in France and it conducts phosgenation at IBIS, its joint venture with Dutch firm Gist Brocades in the U.K.

Patricia Layman

Budget sequester order may nix R&D increases

If the across-the-board budget cuts imposed by President Bush in his Oct. 16 sequester order stick, a number of research agencies are going to find their 1990 budgets growing at a rate well below the 4.2% inflation rate forecast by the Office of Management & Budget—if they grow at all.

Just a few weeks ago, no one really expected the cuts to remain in effect for long (C&EN, Oct. 23, page 5). But Congressional efforts to work out a final version of a reconciliation bill that will raise enough revenue and cut enough federal spending to meet the Gramm-Rudman-Hollings deficit reduction target of $100 billion—give or take $10 billion—for 1990, are proceeding at a snail's pace. Bush has indicated that he'd rather live with sequestered budgets than sign a reconciliation bill that doesn't produce "a real deficit reduction—without new taxes, without spending measures that increase the deficit in the future, and without scoring gimmicks."

One way to accomplish this would be for Congress to omit from the final reconciliation bill a provision canceling the Oct. 16 order. That provision cut civilian research budgets 5.3% and defense R&D 4.3% below the level of funding they had when the order went into effect. The whole federal government, with one exception, at that time was operating under a continuing resolution that essentially just extended the agencies' fiscal 1989 funding.

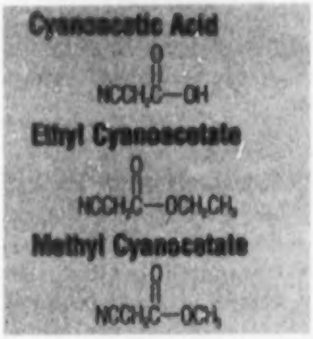
If on Oct. 16, according to an example provided by OMB to explain how the sequester order works, an agency's budget was $100,000, that agency would multiply that number by 0.053, and subtract the result

Across-the-board cuts could stagnate many R&D budgets

	1990 Appropriation			% change 1989–90	
$ Millions	Pre-sequester	Post-sequester	1989	Pre-sequester	Post-sequester
NIH	$ 7,636.0	$ 7,239.8	$ 7,171.5	6%	1%
Cancer	1,664.0	1,577.6	1,570.9	6	0
Heart, Lung & Blood	1,091,3	1,033.9	1,045.7	4	−1
Allergy & Infectious Diseases	846.3	805.5	742.3	14	9
General Medical Sciences	691.9	654.4	682.2	1	−4
Diabetes, Digestive & Kidney Diseases	591.9	561.1	559.6	6	0
Neurological Disorders & Stroke	497.1	470.7	472.3	5	0
Child Health & Human Development	450.6	427.2	425.5	5	0
Research Resources	354.2	334.6	358.3	−1	−7
Aging	243.5	231.2	222.8	9	4
Eye	241.2	228.5	231.3	4	−1
Environmental Health Sciences	233.3	221.0	223.7	4	−1
Arthritis & Musculoskeletal & Skin Diseases	171.7	162.9	160.0	7	2
Dental Research	138.1	130.9	130.8	6	0
Deafness & Other Communication Disorders	119.0	114.3	94.8	25	20
Center for Human Genome Research	60.0	56.8	27.6	117	106
Other	241.9	229.2	224.2	8	2
NASA R&D	**5,281.8**	**5,050.5**	**4,166.7**	**27**	**21**
Energy	**5,266.7**	**5,005.7**	**4,842.5**	**8**	**3**
Energy supply R&D	2,215.5	2,098.1	2,142.3	3	2
Supporting research and technical analysis	680.8	644.7	642.2	6	0
Nuclear activities	590.3	558.6	610.5	−3	−8
Magnetic fusion	326.6	310.2	351.5	−7	−12
Other	616.8	584.6	538.1	15	9
Weapons R&D	1,351.3	1,293.2	1,279.7	6	1
General science and research	1,114.4	1,055.3	922.1	21	14
Fossil R&D	422.1	401.2	380.6	11	5
Conservation R&D	163.4	157.9	117.8	39	34
NSF	**2,066.5**	**1,961.8**	**1,886.7**	**10**	**4**
Research and related activities	1,688.4	1,599.4	1,584.7	7	1
Science education activities	206.7	197.3	171.0	21	15
Antarctic programs	153.7	146.5	131.0	17	12
Academic facilities	9.7	18.6	na		
EPA R&D	**429.0**	**407.4**	**386.5**	**11**	**5**
Commerce	**422.3**	**398.6**	**425.0**	**−1**	**−6**
Oceanic and atmospheric research	172.8	163.8	157.0	10	4
NIST	163.6	154.9	159.0	3	−3
PTO	85.9	79.9	109.0	−21	−27
TOTAL	**$21,104.3**	**$20,063.8**	**$18,878.9**	**12%**	**6%**

Note: All numbers are estimates. na = not available

Cyanoacetic Acid and Esters



Cyanoacetic Acid

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($5300) for a budget of $94,700. That was the only calculation necessary for an agency whose fiscal 1990 appropriation bill had been enacted by Oct. 16. However, if after Oct. 16 Congress appropriated $150,000 for the agency, it had to subtract only the $5300—not a newly calculated $7950—from $150,000 for a fiscal 1990 budget of $144,700.

The one appropriation bill enacted before Oct. 16 provided funding for, among other things, the Department of Energy's research programs. Congress appropriated $590.8 million for basic energy sciences, 7% above the 1989 funding level and just slightly over the budget request. However, the sequester order reduces the fiscal 1990 budget to $559.5 million, just 1% higher than in 1989.

Funding for chemical sciences is similarly hard hit. The Administration had requested a 9% increase to $147.9 million for chemical sciences. Congress approved an 8% increase. But the sequester order leaves that account with a 2.5% increase to $138.5 million. Funding for materials sciences, on the other hand, will still be up 8% to $195.2 million, even after sequester. The Administration had requested a 12% increase to $202 million; Congress approved a 14% increase to $206 million. Congress also provided $220.8 million for the Superconducting Super Collider, including $25 million to initiate construction of the first tunnel sector. After sequester, the SSC will get $209 million.

After a lot of maneuvering the National Science Foundation emerged from the conference committee on the VA-HUD-Independent Agencies Appropriation bill with a budget increase of 8% to $2.1 billion. As a result of the efforts of three conference committee members—Sen. Jake Garn (R.-Utah), Rep. Bob Traxler (D.-Mich.), and Rep. Bill Green (R.-N.Y.)—the conferees decided to fund NSF's research programs at a level of $1.715 billion, $30 million above the recommended Senate level and 8% over fiscal 1989. They found the money for the increase by making a 0.1% reduction in all the other discretionary accounts contained in the bill.

However, what Congress gives, it can also take away. As the conferees were winding up their work they discovered that the total funding provided in the bill exceeded the budget ceiling for those programs. So they cut all the programs funded in the bill by 1.55%, leaving NSF with a research program budget of $1.688 billion, an increase of 6.5%. The sequester order requires NSF to reduce its research budget by just under $90 million, leaving it with a bare 1% increase for fiscal 1990. This translates to 700 fewer grants than would have been awarded before the sequester.

One bit of good news is that for the first time the fiscal 1990 budget provides money for the long-planned

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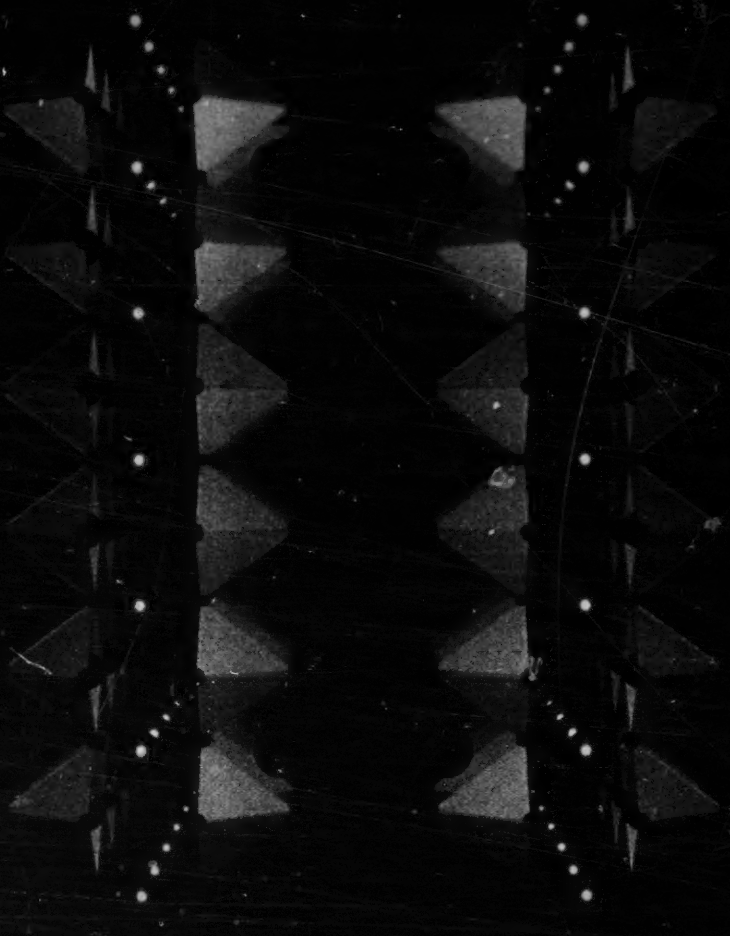
NOVEMBER 27, 1989

CHEMICAL & ENGINEERING NEWS



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High-Temperature Superconductors

Advances made in applications of new materials
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CHEMICAL & ENGINEERING
NEWS

Volume 67, Number 48
CENEAR 67 (48) 1–76
ISSN 0009-2347

NOVEMBER 27, 1989

News of the Week

- **New analysis by NOAA researchers suggests that significant ozone loss may be occurring at high southern latitudes outside the Antarctic ozone hole.** Page 6
- **Bush stance on chemical arms continues to stir confusion, concern, and opposition both within the U.S. and overseas.** Page 7
- **Clean air legislation to have priority on Senate agenda when Senate reconvenes on Jan. 23.** Page 7
- **S. Allen Heininger, corporate vice president for resource planning at Monsanto in St. Louis, has been elected ACS's 1990 president-elect.** Page 7
- **The European Community is on the verge of offering free-trade status to six oil producing countries in the Middle East.** Page 8

Cover: Computer-generated crystal structure of yttrium-barium-copper oxide high-temperature superconductor. Photo courtesy of IBM

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Business

Polypropylene fortunes have dimmed, with decreasing demand and expanding capacity leading to lower prices and profits. Page 29

East bloc industry likely will become more trade- and customer-oriented as a result of current moves in Eastern Europe toward democratization. Page 32

Government

Academies' report calling for farmers to adopt low-input methods is drawing heavy criticism. Page 38

NIH-proposed ethical guidelines for researchers are widely regarded as overkill. Page 42

FDA Commissioner Frank Young will leave the agency for a new post at the Department of Health & Human Services. Page 45

Science/Technology

U.S. holds back on rejoining UNESCO during recent Paris meeting but sends observers to discussions involving group's science, education programs. Page 47

Education

Report, recommendations on science education presented to Congress by ACS's Society Committee on Education. Page 54

News Focus

In push toward commercialization of high-temperature superconductors, big firms, startup companies, industry consortia, government agencies, and national labs are striving to perfect the processing of the ceramic materials. Page 9

Chemical & Engineering News
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LETTERS

Liquid oxygen hazard

SIR: I am writing in reaction to the letter of M. H. Gitlitz (C&EN, Sept. 25, page 5) on informed risk perception. I quite agree with his conclusions about the need for rational attitudes about chemicals among the public, firefighters, and the media; however, the example he cites of an inappropriate response having to do with spillage of liquid oxygen on the New Jersey Turnpike may, in fact, have been an appropriate response. According to R. Gerlach in an article titled "Flammability, Combustibility" [in Young, J. A., editor, "Improving Safety in the Chemical Laboratory: a Practical Guide," Wiley-Interscience, New York, page 75 (1987)], "Liquid oxygen in contact with combustible materials can cause spontaneous fires to erupt. When liquid oxygen soaks into relatively noncombustible asphalt, the combination is a high explosive, sensitive to heat or shock." If the segment of the New Jersey Turnpike in question was asphalt, then the emergency response was appropriate.

Nancy M. Tooney
Associate Dean of Arts and Sciences,
Associate Professor of Biochemistry
Polytechnic University

Monosaccharide linkages

SIR: The article by Stephen Stinson, "Controlled Linkage Techniques for Monosaccharides Introduced" (C&EN, Aug. 28, page 25), reviewed two reports from Samuel Danishefsky's laboratory that were published in the *Journal of the American Chemical Society*. Although not wishing to comment on the chemistry that is introduced in these articles, I would like to remind (or inform) your readers of prior art in four relevant areas of carbohydrate chemistry so that proper historical perspectives will be preserved.

First, no discussion of controlled linkages of monosaccharides via 1,2-anhydro sugars should ignore Raymond Lemieux's 1953 triumph over sucrose [*J. Am. Chem. Soc.*, **75**, 4118 (1953)], described even today by R. T. Morrison and R. N. Boyd ["Organic Chemistry," 3rd ed., Allyn and Bacon Inc., Newton, Mass. (1987)], as "the Mount Everest of organic chemistry."

This omission may be attributable to the opening sentence of the second JACS article [**111**, 6661 (1989)]: "The possibility of using 1,2-anhydro sugars as glycosyl donors has been recognized, but not extensively exploited." These assessments do not convey the painstaking and scholarly series of investigations that led to Lemieux's conquest. Thus, Stinson's "α-epoxides" are similar to Brigl's anhydride, the reactions of which have been investigated by carbohydrate chemists for 50 years. Lemieux's pivotal observation was that primary alcohols opened the epoxide to give trans products (i.e., β-glucosides), whereas hindered alcohols gave appreciable cis openings (i.e., α-glucosides). The rationalization of these results was a triumph for conformational analysis, made more impressive by the then embryonic nature of that concept. The "alcohol" on the fructose moiety of sucrose is tertiary, hence the logic of his achievement.

Second, the single mention of Lemieux's work in the C&EN article comes in paragraph 11 in connection with the haloalkoxylation of glycals described in the first JACS article [**111**, 6656 (1989)]. Lemieux developed iodonium dicollidine perchlorate expressly for use with glycals, and in considering the "controlled linkage [of] monosaccharides," your readers might be interested to know that the reagent was used by David Iley in our laboratory for the key step leading to the first strategically different (and the first completely stereoselective) route to sucrose [*J. Am. Chem. Soc.*, **97**, 2563 (1975)].

However, of much greater impact is the extensive body of work by Joachim Thiem over the last 10 years, described in over 40 papers, which include important strategies for synthesizing the troublesome 2-deoxy-β-anomers. His syntheses of the oligosaccharides from the aureolic acids, mitramycin, digitoxosides, and anthracyclines, are representative of his expertise.

Third, the subhead of the C&EN article, "Methods allow automation of oligosaccharide production..." echoes the final sentence of the second JACS article: "Possibilities of a reiteratable and automatable scheme for oligosaccharide synthesis...are currently being evaluated." In view of the absence of appropriate citations, your readers should be aware of the pioneering and extensive work of Scheurch (U.S.), Frechet (Canada), and Kochetokov (U.S.S.R.) for nearly 20 years on both solid-phase and polymerization routes to oligosaccharides. Those inclined to compare oligosaccharide and oligonucleotide automated syntheses ignore the stony terrain covered by these investigators at their peril.

Fourth, in amplification of the fifth paragraph of the C&EN article, it should be noted that the idea of utilizing a functional group in oligosaccharide synthesis to "control the traffic" (to use

Overcapacity Slimming Earnings For Polypropylene Producers

Decreasing consumption and expanding capacity are driving down operating rates, resulting in price cuts and lower profits

Bruce F. Greek, C&EN Houston

Polypropylene, which for three years was riding the crest of a major boom, has slipped into leaner times. All the signs point to lower profits for producers. Reduced demand and expanding facilities are leading to overcapacity with attendant price cuts to maintain competitive positions. Export prices for homopolymer grades of polypropylene, for instance, have dropped to half those of late spring, and prices for sales within the U.S. have dropped to a third of what they were.

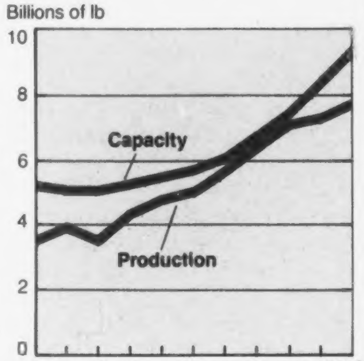
Polypropylene output this year will grow at the lowest rate since the recession of the early 1980s. Capacity expansions now completed or expected to be completed in 1990 will far exceed demand growth. Within a year, overcapacity will drive down average plant operating rates to about 83% of nameplate capacity, the lowest in seven years. Except in the limited volume specialties, selling prices of most polypropylene resins have fallen since the summer, as the size of the overcapacity and the excessive inventory growth have become evident.

Polypropylene was first of the large-volume plastics to enter the current cycle of demand buildup, capacity expansion, and subsequent overcapacity. Demand for the plastic soared in 1986, while demand for other plastics recovered more slowly from the recession. Improved polymerization technology and low prices led to the production of numerous new polymers and to new uses of polypropylene, spurring unexpected demand. Continued strong exports also helped to increase demand. With demand at an apparently insatiable point, prices soared to new highs for recent times.

By the second quarter of this year, polypropylene demand and pricing had peaked, according to several industry sources. Interpolymer competition became serious and exports declined slightly, which started a slide in demand and prices. Inventory building, already under way, increased as new capacity for polypropylene came on stream. Spot prices for resins going to export markets recently fell to less than 30 cents per lb, half of spot prices about a year ago. The slumping prices then started the expected pulldown of inventories.

Under the pressure of capacity additions for next year forecast at as much as 15% of those in mid-1989, prices will weaken further, according to industry sources. Polymer-grade propylene prices also have fallen. The declines in propylene prices reflect efforts by monomer producers to bolster polymer profit margins and also are a reaction to additional propylene production and purification capacity that has come on stream this year. Unless current crude oil and natural gas prices go even higher, propylene prices likely will follow ethylene prices down, as the wave of new steam-cracking capacity starts up. Lower prices for the monomer will somewhat help margins, as polymer prices keep sliding.

Polypropylene output slows as capacity climbs



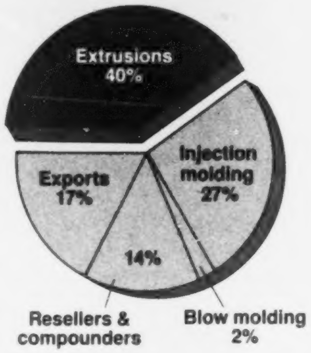
[a] Forecast. **Sources:** Committee on Resin Statistics of the Society of the Plastics Industry, C&EN estimates

Lower prices and increased overcapacity for polypropylene will continue for at least another year. The plastic will regain some of the uses lost to other polymers, and development of new uses will be spurred, as happened during the first half of the 1980s. The shift toward greater use of polypropylene in various fabricated items will accelerate temporarily as a result of the recent loss of a large amount of Phillips 66's capacity to make high-density polyethylene (HDPE) because of an explosion and fire at its Pasadena, Tex., plant (C&EN, Oct. 30, page 4). Spurred by lower prices, demand will begin to grow substantially again in the early 1990s, according to industry sources. Hence, polypropylene will have the advantage of being the first of the major polymers to have tight supply with rapid runup in prices, followed by large capacity buildup, oversupply, and slump in prices, with the cycle repeating itself.

Meanwhile, polypropylene producers must cope with a profit squeeze and lower capacity use. The methods they are using to overcome these problems make it difficult to forecast production and capacity use in 1990. For example, inventory reduction under way during the third quarter of this year was larger than expected as, at the same time, production was reined in. This meant that smaller quantities of higher cost polymer (based on present monomer and processing costs) were made that will need to be sold at low margins to compete with the lower cost polymers now being produced and those to be produced later.

Relative to output, however, inventory reduction will be small. For example, during the first six months of this year, polypropylene production totaled 3.80 billion lb, according to preliminary estimates by the Committee on Resin Statistics of the Society of the Plastics Industry as compiled by Ernst & Young. During the same period, sales and captive use totaled 3.68 billion lb. Therefore, about 120 million lb of polypropylene, or about 3% of production, must have gone into inventory. With production at more than 600 million lb per month, such an inventory addition could be eliminated in a few months through relatively minor reductions in plant operations, including shutdowns for maintenance.

Extrusions are biggest market for polypropylene



Total 1988 consumption = 7.1 billion lb

Sources: Committee on Resin Statistics of the Society of the Plastics Industry, C&EN estimates

The polypropylene inventory undoubtedly was reduced during the third quarter and so far in the fourth quarter. Inventory reduction has been unexpectedly high as a result of the shutdown of Phillips' polypropylene unit at Pasadena coincident with the disaster at the firm's HDPE plant. Phillips restarted the polypropylene unit with 480 million lb of annual capacity earlier this month.

The industry's inventory-building in the first half of this year may have been a carryover from 1988 when annual production exceeded sales and use by more than 180 million lb. The 1988 production excess over demand followed a 1987 inventory reduction, when the boom in demand for polypropylene continued after rapid growth that began in 1986.

Production of polypropylene in the first six months of this year, at 3.80 billion lb, up 5.9% over production in the first half of 1988, could be a record that will last another year. Despite capacity additions during the second half of this year of nearly 10% of total capacity at the beginning of the year, industry sources forecast that output in the second half will be lower. Forecasts call for production to be down 100 million to 200 million lb for the second half of 1989, bringing the annual total to about 7.5 billion lb.

Sales and captive use of polypropylene during the first six months of this year were up 3.3% over the nearly 3.6 billion lb of the first half of 1988. This growth in consumption was somewhat lower than the 4 to 5% forecast for demand growth for polypropylene during 1989. Forecasters now say that, unless exports spurt unexpectedly, sales and use will not increase much more during the second half of this year. A slight gain may result from inventory reduction efforts and from any shift late in this quarter to the use of polypropylene from the use of HDPE (as a result of the tightened supply and higher prices of HDPE).

Inventory reduction could be even larger than expected if producers with older polymerization units decide that prices have fallen to unprofitable levels and that these units should be mothballed, as some were five years ago. Improving production economics through conversion to more efficient catalysts and through other process changes may not be justified as margins slide and further add incentive to reduce plant operations.

Plant operating rates have been dropping for several months and are expected to continue to drop during the rest of this year and most of next. This year, if 7.5 billion lb of polypropylene are produced and average plant capacity is 8.5 billion lb, the operating rate will be 88.2%, down more than 10% from the 97.3% of nameplate capacity estimated for 1988 (which was a record year).

Falling prices are expected to spur demand next year for both U.S. consumption and for exports, which may reach 1.4 billion lb this year, up from about 1.2 billion lb in 1988 as reported by SPI. Exports could be threatened by new polypropylene capacity to be completed in various parts of the world but especially in the Far East. However, supplies of propylene for these plants are marginally sufficient, and polymer producers face competition from other uses of propylene.

Demand growth in the U.S. is forecast to follow the pattern set recently, with extrusions (especially fibers) continuing to lead. The nonwoven fiber products market, coming from a relatively small base, will grow markedly and may account for more than 8% of consumption of the polymer in 1990, or about half that in woven fiber products. Fiber and filament end-products made using polypropylene will account for more than 28% of total U.S. consumption this year. Filaments will go into such products as rope, twine, decorative ribbon, and bristles. Extruded film, especially the oriented types, used mainly in packaging will be about 10% of consumption and will grow about 7% this year.

Other fast-growing uses are largely in consumer products, mostly formed by injection molding. Examples include furniture such as outdoor seating, housewares, office equipment such as desk files and other small items, luggage and briefcases, toys, and other leisure use items. Injection-molded products forecast to grow more slowly as markets for polypropylene are various appliance parts, cases for automobile storage batteries, and caps and closures. □

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1990 Pittsburgh Conference program Page 49

DECEMBER 4, 1989

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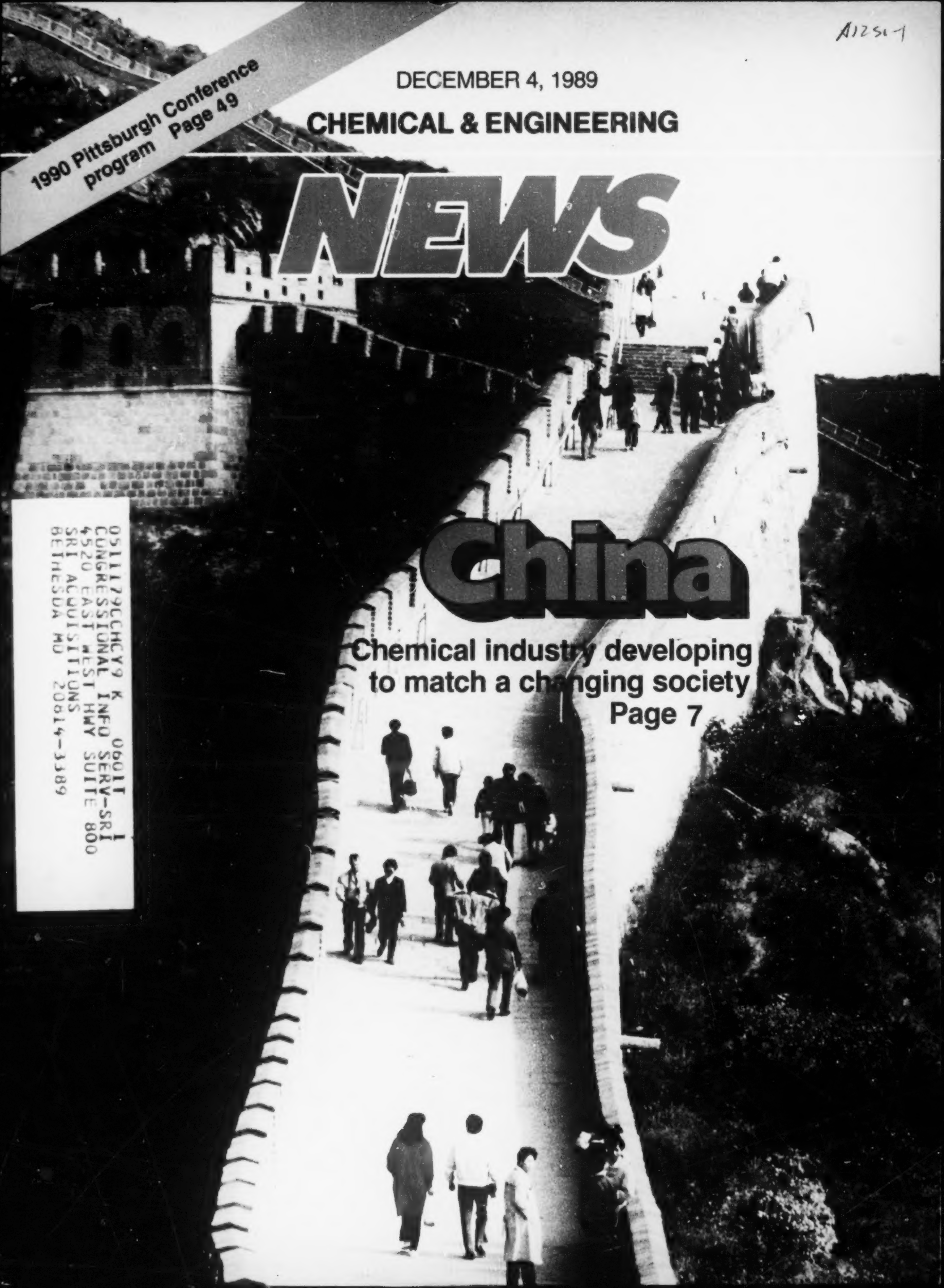

China

Chemical industry developing to match a changing society

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- **Sovlets agree to joint venture with Combustion Engineering and Neste.** Page 4
- **Protein engineering research facility, a joint government/industry/ academic project, opens in Maryland.** Page 5
- **HCFCs, halons, carbon tetrachloride, methyl chloroform may face phaseouts similar to those currently set for CFCs.** Page 5
- **Bhopal disaster remains unsettled as Indians, U.S. groups mark five-year anniversary.** Page 6

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Business

Merck Frosst, other Canadian drug companies are hiking R&D spending, following legislation granting patent for new compounds. Page 16

Government

Final set of proposed rules dealing with land disposal of hazardous wastes has been completed by Environmental Protection Agency. Page 19

Science Policy

NAE president, Robert M. White, discusses challenges of engineering academy, which just turned 25, as it moves into its next phase. Page 22

Science/Technology

Discovery of catalytic RNA, which won 1989 Nobel Prize in Chemistry, was made independently, in different labs, by two scientists. Page 31

Suggestions for managing mixed low-level radioactive waste are made in report by Congress' Office of Technology Assessment. Page 34

Books

"Serendipity: Accidental Discoveries in Science," by Royston Roberts, succintly recounts over 100 serendipitous discoveries. Page 35

ACS News

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1990 Pittsburgh Conference miniprogram includes symposia sessions, registration, and other information. Page 49

ACHEMASIA '89

News Focus

Recent ACHEMASIA '89 meeting, hosted for the first time by China, featured variety of exhibits and technoeconomic lectures as well as discussions on past, present, and future of Chinese chemical industry. Page 7

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LETTERS

Credentialing program

SIR: In response to the letter from Michael K. W. Li (C&EN, Oct. 16, page 4) concerning the usefulness of a professional title for consultant chemists and others, I suggest he investigate the credentialing program of the National Certification Commission in Chemistry & Chemical Engineering. As sponsored by the American Institute of Chemists, it confers the status of Certified Professional Chemist and/or Certified Chemical Engineer to those who qualify.

Both titles have been accepted by the courts as to the credibility of expert witnesses and have won recognition elsewhere by consultants' clients and by others. Applications for the 1990 program are now available.

David A. H. Roethel
Executive Director, National
Certification Commission in
Chemistry & Chemical Engineering
Bethesda, Md.

Alar controversy

SIR: For some time, I have hesitated to address you on matters of publication policy. But now, when the National Academy of Sciences recommends that federal policies be reversed which, for four decades, have focused on increasing the productivity of crop and livestock farms through heavy use of pesticides, drugs, and synthetic fertilizers, I must let you know about the reservations I have when it comes to Ann M. Thayer's article, "Alar Controversy Mirrors Differences in Risk Perception" (C&EN, Aug. 28, page 7). Although I must compliment her on her perceptive treatment of the subject, I wish she had looked at it from a broader perspective.

In the first paragraph of her article, Thayer lets it be known that "the debate was rife with charges that the public and media overreacted, the government underreacted, and interest groups and industry misled the public." Thereby she identified the five actors in this dramatic situation: The public, the media, the government (Environmental Protection Agency), the interest groups, and Uniroyal Chemical Co., the industrial producer of Alar.

She did not even mention the most important and objective actor—the scientific community. It was represented by Bruce N. Ames, chairman of the department of biochemistry, director of the National Institute of Environmental Health Sciences Center at the University of California, Berkeley, and a member of the National Academy of Sciences.

The important scientific contribution of Ames has been the discovery that many of our vegetables contain nature's pesticides—for example, natural chemicals that cause cancer in rats or mice and that are present in enormously higher concentrations than the industrial chemicals present in the pesticide residues in plant foods. It is for that reason that his estimate for the number of cases of cancer or birth defects caused by man-made pesticide residues in food or water pollution—usually at levels hundreds of thousands or millions of times below that given to rats or mice—is close to zero.

The debate began in February when the Natural Resources Defense Council (NRDC), an activist environmental group, released a report charging that a by-product of Alar is an animal carcinogen that poses an imminent hazard to humans, particularly children. Ames responded and declared in the *Los Angeles Times*, Feb. 27, 1989, that the Food & Drug Administration and EPA are much more competent in doing a good job of protecting our food supply from carcinogenic contaminants than the activist lawyers with NRDC who spend their time wooing the media with scientifically unfounded claims about the dangers of pesticides, but who have never assembled a knowledgeable board of scientific advisers.

There followed the publication of two letters in the May 19, 1989, issue of *Science*. Under the title "Alar in Apples," Edward Groth III of the Consumers Union of the United States Inc. makes his position quite clear. "The scientific facts (estimates of how big the risk is, with all the inherent uncertainties) are just part of what the public knows about Alar. The policy choices—both the personal and public kind—depend on far more than facts. However big a risk may be, whether it is acceptable or not is a value judgment and is heavily influenced by moral dimensions of the risk."

Ames, in collaboration with Lois Swirsky Gold, writes under the title "Pesticides, Risk, and Applesauce." In his concluding paragraph he states: "Regulation of low-dose exposures to chemicals, based on animal cancer tests, may not result in significant reduction of human cancer, because we are exposed to millions of different chemicals—almost all natural—and it is not feasible to test all of them. Most exposures, with the exception of some occupational, medical, or natural pesticide exposures, are at low doses. The selection of chemicals to test, a critical issue, should reflect human exposures that are high doses relative to their toxic doses

China's Chemical Industry Is Focus of ACHEMASIA '89

Joint West German-Chinese effort—ACHEMASIA '89—brought chemical engineers and biotechnologists to Beijing for exhibits and technoeconomic lectures as well as discussions of status of China's chemical industry

Joseph Haggin, C&EN Chicago

The Chinese chemical industry is simultaneously old and new. Development of gunpowder, paper, and alcoholic beverages began centuries ago, but the modern chemical industry dates only from the early 1980s.

In between, chemical production was highly localized, typified by an early lead-chamber sulfuric acid plant operating in Tianjin in 1876. Other early plants made such basic products as soda ash, synthetic ammonia, nitric acid and explosives, and a few organic chemicals from coal tar.

Despite a long tradition of science that may be venerable and comforting, China faces immense challenges in providing for a modern, constantly changing society in excess of a billion people. In short, what China needs is a large and modern chemical industry that can provide and ensure future stability and a higher quality of life. The Chinese know this better than anyone, and, for at least the past 13 years, they have been progressing rapidly, if not always steadily, toward that end.

C&EN staff photo

Flags decorate entrance to ACHEMASIA '89 exhibition hall

Evidence of such industrial progress came this fall at an exhibition and congress held in Beijing. A joint West German-Chinese effort called ACHEMASIA '89, the international meeting on chemical engineering and biotechnology occurred as planned, although it had been threatened with cancellation as a protest against the killings of demonstrators at Tiananmen Square early this summer by the Chinese government.

Technoeconomic lectures by industry officials at the ACHEMASIA congress drew a profile of the Chinese chemical industry and the changes it is undergoing. An overview of the more recent development of the industry was presented by Chen Jianyuan, chief engineer of China's Ministry of Chemical Industry.

Several state ministries and corporations manage China's chemical industry. The managerial structure is constantly changing, but control at present is manifested through four major organizations: the Ministry of Chemical Industry, China Petroleum Corp. (SINOPEC), the China State Pharmaceutic Administration, and the Ministry of Light Industry. The division of responsibility between these organizations is not rigid, and occasional ad hoc arrangements are made between them for particular purposes. For ex-

Four government organizations manage Chinese chemical industry

Ministry of Chemical Industry

- Fertilizers and agrochemicals (such as ammonia, pesticides)
- Basic chemicals (including sulfuric acid, soda ash, caustic soda)
- Coal chemicals (including calcium carbide, PVC, methanol)
- Fine chemicals (such as coatings, dyes, reagents, adhesives)
- Rubber products (such as tires, belts, hoses)
- Polymers (including polyolefins, acrylics, fluoropolymers)
- Special chemical ores
- Miscellaneous

China Petrochemical Corp. (SINOPEC)

- Petroleum refineries within China
- Petrochemicals (ethylene and derivatives, most organics)

China State Pharmaceutic Administration

Ministry of Light Industry

- Plastics processing, fabrication, and the like (mostly consumer products)
- Consumer specialties (such as detergents, cosmetics)
- Paper, leather, and miscellaneous items

Source: Chinese Ministry of Chemical Industry

ample, says Chen, coal tar chemicals are usually produced as by-products of steel making, thus they are usually managed by the Ministry of Metallurgical Industry.

According to Chen, in 1949, the total production of chemicals and related products in China was valued at about $45.7 million. In 1988, the gross value of chemicals and related products had grown to $18 billion. Most of production is in nonpetrochemical products. The progress chalked up by the industry is attributed to the success of the series of government-devised five-year economic plans that began in 1953.

Between 1953 and 1957, three state-owned chemical corporations were organized by the Ministry of Heavy Industry. Jilian Chemical Corp. made synthetic ammonia, nitric acid, ammonium nitrate, methanol, acetic acid, and other products using coal and coal tar as raw materials. Lanchow Chemical Corp. made butadiene-styrene rubber, butadiene-acrylonitrile rubber, polystyrene resins, and nitrogen fertilizers. Taiyuan Chemical Corp. produced insecticides, pesticides and agrochemicals, caustic soda, chlorine, nitrogen fertilizers, sulfa drugs, and vitamins. Another pharmaceutical plant began making antibiotics about the same time. Between 1958 and 1965, additional chemical plants began production of photographic products, inorganic chemicals, vinyl materials, polyamide fibers, polyvinyl chloride resins, and other plastics.

Development of the chemical industry, according to Chen, experienced some severe setbacks during the Cultural Revolution, which marked the decade ending in about 1976. Gross output dropped more than 10%. However, a number of small ammonia plants were built, and one naphtha cracking unit was placed in service. Most of these units were purchased from Japan and the U.S.

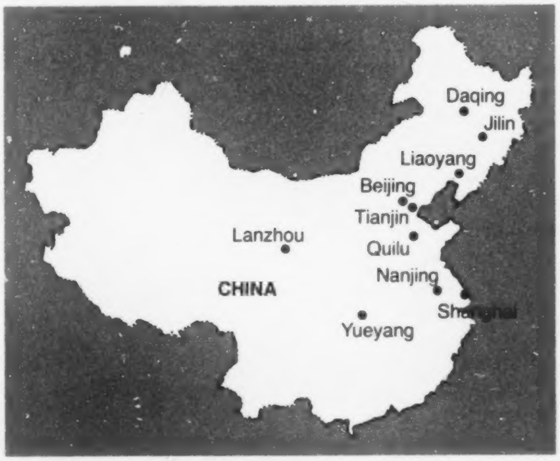
The government, Chen says, is also encouraging development of the petrochemical industry in the expectation that oil reserves will be developed in the South China Sea and in Guangdon, Fujian, and Hainan provinces. The government projects ethylene production will reach 2 million metric tons per year in 1990 and 3 million metric tons per year by the end of the century.

Most of the immediate improvements in the Chinese chemical industry are being made with the aid of imported technology and equipment. However, Chen adds, China recognizes that it must develop its own technology and is intensifying industrial research and is rapidly augmenting university training for scientists and engineers. China's goal is to acquire long-term continuity in R&D activities for industry.

A more specific look at the petrochemical industry was provided by Zhang Shi, a professor at Shanghai Research Institute of Petrochemical Industry and a representative of SINOPEC. The industry traces its origin back to a decision of the central government in 1956 to enhance crude oil production. Basic developments were carried out in Shanghai, Beijing, and Shanyan. The first petrochemical units were built and operated in Shanghai and Lanzhou using refinery gas as a feedstock.

In 1959, imported technology permitted production of 35,000 metric tons per year of ethylene from heavy oil. The downstream products issuing from this base were low-density polyethylene, polypropylene, acrylonitrile, acrylic fibers, and polypropylene fibers. Most of the plants were small and aimed at satisfying local needs. This picture remained more or less fixed until another basic decision of the government in the early 1970s decreed the further importation of technology and a new capacity increase. By the end of 1988, the

Chinese petrochemical industry is concentrated in eastern provinces



industry had reached a plateau; any further change in the industry's growth will be dependent upon upcoming five-year plans.

Most petrochemical enterprises are operated by SINOPEC, which was organized by the government in 1983. In 1988, sales revenue for SINOPEC was about $13.4 billion, with a net profit of $4.25 billion. SINOPEC controls 94% of the national refinery capacity and 85% of ethylene capacity. Other state agencies control the remainder.

With the development of the Daqing oil field in 1960 and the Shengli oil field in 1965, the petrochemical industry had sufficient feedstocks available to operate.

The petrochemical industry in China began with the completion of an ethylene plant at Daqing in 1986. Two others—Qilu and Yangzi—went on stream in 1987. Another is now under construction in Shanghai. Each of the plants will produce about 300,000 metric tons per year. In subsequent years, other fields in Dagang, Fuyu, Jianghan, and Liaohe contributed additional production, such that present refining capacity exceeds 7 million metric tons.

However, Zhang adds, distribution remains a problem. The original oil fields were seldom located close to refineries, which tended to be small and localized. Consequently, it was difficult or impossible to supply the appropriate feedstocks to all refineries. For reasons such as these, the petrochemical industry developed in a pattern determined by the availability of feedstock.

Before 1970, most of the plants for producing petrochemicals were the result of government R&D efforts being gradually extended to semiworks. The large manufacturing plants did not appear until the early 1970s. Then, imported technology was acquired for large-scale production of ethylene, polyethylene, polypropylene, ethylene glycol, polyesters, acrylonitrile, and other materials of commercial importance.

By 1980, China had contracted for four 300,000 ton-per-year ethylene plants and for corresponding downstream facilities. According to Zhang, all of these will be on stream by 1990. In addition to these, a smaller 115,000 ton-per-year plant was built at Jilin in 1982.

Despite the progress in acquiring chemical plants, Zhang says the industry's maximum production is still far short of demand, and imports have continued to rise apace. The problems have been somewhat inflamed by a sharp rise in ethylene prices in 1987.

The petrochemical industry is capital-intensive, a major reason, according to Zhang, for the strong emphasis on foreign joint ventures currently under way in China. Strong emphasis on foreign capital acquisition is likely to continue for the next several years, coupled with the maximum possible domestic development, to eventually reduce chemical imports to an acceptable level.

Some major petrochemical plants operating in China

Plant/location	Refinery capacity (thousands of metric tons)	Ethylene capacity (thousands of metric tons)	Principal products
Lanzhou Chemical Industry Co., Lanzhou	—	100	Rubber resin
Gaoqiao Petrochemical Co., Shanghai	4500	15	Resins, organic raw materials
Yanshan Petrochemical Co., Beijing	7000	300	Rubber resin
Shanghai General Petrochemical Works, Shanghai	2800	120[a]	Fiber resin
Liaoyang Petrochemical Fiber Co., Liaoning Province	1500	73	Resin, fiber
Daqing General Petrochemical Works, Daqing	5000	300	Resin, organic raw materials
Quilu Petrochemical Co., Shandong Province	6000	300	Resin, organic raw materials
Yangzi Petrochemical Co., Nanjing	3000	300	Resin, organic raw materials
Jilin Chemical Industry Co., Jilin	2500	115	Organic raw materials
Yueyang General Petrochemical Works, Yueyang	—	—	Liquefied petroleum gas, organic raw materials
Tianjin Petrochemical Co., Tianjin	3500	—	Benzene-toluene-xylene, fiber

[a] 300 under construction. **Source:** China Petrochemical Corp.

Ethylene production, capacity increase sharply

Thousands of metric tons	1988	1987	1986	1985	1984	1983
Ethylene (capacity)	960.0 (1620)	820.0 (1600)	695.3 (9800)	652.1 (680)	648.0 (680)	653.7 (680)
Plastics resin	986.8	730.0	1322.5	1232.7	1179.9	1121.0
Synthetic fibers and monomer	1420.4	1330.0	1904.3	1871.4	1382.4	957.3
Synthetic rubber	192.5	150.0	188.4	180.1	170.0	168.0

Source: China Petrochemical Corp.

In light of China's enormous population, food production remains the first priority of the government. More than 100 cities in China have populations of more than 1 million, and there are several hyperintensively populated regions around such cities as Beijing, Shanghai, and Guangzhou (Canton). Nevertheless, about 80% of the Chinese population is still considered rural, and much of that population are farmers.

The problems of generating high enough food production rests in large measure on the success of fertilizer manufacture. The current situation in this industrial sector was put into perpective at the ACHEMASIA congress by Liang Zhifang, senior engineer at Shanghai Research Institute of Chemical Industry. She noted that China, with a quarter of the world's population, has only 7% of the arable land. Thus, increasing unit area production is highly important, and chemical fertilizers have been responsible for much of the success so far. This success, Liang adds, has not been achieved without some problems as well, but there seems to be no other course to follow than the ever larger use of chemical fertilizers.

China breaks new ground by hosting international science, technology meeting

If China can't come to the fair, take the fair to China! That seems to have been the philosophy behind ACHEMASIA '89, a joint effort between West Germany's Deutsche Gesellschaft für Chemisches Apparatewesen, Chemische Technik und Biotechnologie, or DECHEMA (German Society for Chemical Equipment, Chemical Technology & Biotechnology), and the Chemical Industry & Engineering Society of China, or CIESC.

ACHEMASIA '89—an international meeting on chemical engineering and biotechnology and the first of its kind in China—had been in preparation for several years. As the date for the event neared, it had been threatened with cancellation when China's repressive policies intensified following the events of early June in Tiananmen Square. However, the resolve of the organizers and participants to proceed was fortified by the nonrefundable investment required of the exhibitors, and the exhibition/congress was held as planned.

The main purpose of ACHEMASIA '89 was to make European, Japanese, and North American chemical engineering and biotechnological know-how more widely available in Asia. Asia's population growth begets economic growth. Supporting both will require the application of chemical engineering and biotechnology, much if not most of which will come from Europe, Japan, and North America.

In addition to DECHEMA and CIESC, other groups supporting ACHEMASIA included the Ministry of Chemical Industry of China, China's Chemical Planning Institute, China Petrochemical Corp., China International Trust & Investment Corp., the European Federation of Biotechnology, and the European Federation of Chemical Engineering.

Although there was some representation from Japan, the U.S., and the rest of Europe, the exhibition/congress, not surprisingly, was mainly a German "show." A total of 335 exhibitors manned the booths including 119 from China itself. The premeeting publicity suggested 40,000 visitors but observation indicated less than that number. There were also about 200 lectures and seminars, attended by about 1800 people.

Beijing was the organizers' choice as the location for ACHEMASIA '89 because of the economic and political stability demonstrated in China and other Asian countries and because of the recognized need for establishing long-term relations with potential partners and customers in China. The general format is that of the ACHEMA exhibition/congresses produced by DECHEMA in Frankfurt every three years. Since the organizers of the recent ACHEMASIA '89 intended to make the exhibition/congress the basis for continued development of professional and business contacts, the original decision was to hold an ACHEMASIA meeting every other year. That decision is now under review by the sponsors.

DECHEMA is a not-for-profit technical and scientific society established in 1926. Currently under managing director Dieter Behrens, it provides educational and informational products and services and conducts research for its members. An integral part of the organization is the DECHEMA Institute, founded in 1961 by Karl Winnacker. The institute is staffed by about 80 people who perform research and conduct technical consultation for members.

The principal activity of DECHEMA, however, is the ACHEMA exhibition/congress. ACHEMA is an acronym for Austellungs-Tagung für Chemisches Apparatewesen (chemical engineering exhibition and congress). The first was held in 1920 before DECHEMA was formally organized and had 75 exhibitors. The most recent ACHEMA was in 1988 and had 2800 exhibitors and about 250,000 visitors.

At ACHEMASIA '89 there were four American representatives—Du Pont China Ltd. (Hong Kong), Mixing Equipment Co., Yellow Springs Instruments Inc., and Bepex Corp. The profusion of equipment and instruments usual for such events was not in evidence at the exhibition. Logistical problems of getting equipment in and out of China and indecision caused by the events of June discouraged elaborate displays. However, there was brisk business in technical literature and personal consultations. The most well-attended seminars were not the technoeconomic lectures, as the organizers had anticipated, but those dealing with hands-on laboratory and plant experience.

If ACHEMASIA '89 was primarily a German show in execution, it was primarily a Chinese show in reception. A lot of consultation remains to be done to unite the twain.

In the 20 years prior to 1970, world grain output doubled. The United Nation's Food & Agriculture Organization attributes between 40 and 70% of this increase to use of chemical fertilizers. The Chinese experience parallels these data. More than 163 million metric tons of grain were produced in 1952 using 78,000 tons of chemical fertilizers. The totals rose to more than 400 million metric tons of grain produced in 1987 using 20 million metric tons of fertilizers.

Before 1970, Liang says, most of the fertilizers produced in China were made using domestic technology, with small plants being widely dispersed to meet local needs. More than 1000 such plants were in production. During the 1970s, 13 large nitrogen fertilizer plants and four large ammonia plants were imported. There are now more than 2000 fertilizer plants producing such chemicals as ammonium sulfate, ammonium nitrate, ammonium bicarbonate, urea, calcium cyanamide, aqua ammonia, anhydrous ammonia, ammonium chloride, single- and triplesuperphosphate, ammonium phosphates, potassium chloride, and numerous micronutrients. China is now the third largest producer of chemical fertilizers in the world following the U.S. and the U.S.S.R.

According to Liang, despite such a high level of fertilizer production, demand still exceeds supply. Imports still account for some supply, but the country intends to limit imports as soon as possible. The stated

China produces variety of inorganic chemicals

	% total chemical production		% total chemical production
Arsenic compounds	0.3%	**Magnesium compounds**	2.5%
Barium compounds	2.0	**Manganese compounds**	2.8
Borides and borates	7.6	**Molybdenum, titanium, vanadium, tungsten, zirconium**	5.6
Bromides and bromates	2.5	**Nitrates**	4.3
Carbonates	5.3	**Oxides**	4.8
Chlorides and chlorates	11.5	**Peroxides**	1.0
Chromium compounds	3.6	**Phosphorides and phosphorates**	8.9
Cyanides	3.8	**Silicides and silicates**	5.2
Fluorides	5.3	**Sulfides and sulfates**	9.8
Hydroxides	2.0	**Other**	10.2
Iodides and iodates	1.0	**TOTAL**	100.0%

Source: Tianjin Research Institute of Chemical Industry

goal of the Chinese government is to provide 400 kg of grain per person in China by the end of the century. The forecast is that chemical fertilizer demand will rise to about 30 million metric tons by the year 2000.

In the case of nitrogen fertilizers, Liang says the preferred production technology will be based on coal. This implies much development work on coal gasification and the generation of synthesis gas. Phosphate fertilizers will be based mostly on abundant phosphate ores from Yunnan and Guizhou provinces. Where possible, the production of phosphate fertilizers will be linked with the production of electricity. A major deficiency will be sulfur. China has limited sulfur deposits, and there is a good possibility that gypsum and other secondary sources of sulfur will be utilized. China is also poor in potassium sources. Domestic sources will be sought, but imports may become necessary.

In the immediate future, the construction of "built-in-China" fertilizer plants will become the norm. By the end of the century, new large-scale plants will be built by Chinese industry, and existing plants will be modernized as rapidly as possible.

Inorganic chemical production in China was described for the Congress by Sun Wei, an engineer at Tianjin Research Institute of Chemical Industry. The tonnage of inorganic chemicals ranks third behind fertilizer and sulfuric acid, with the largest manufacturing center being Shanghai. Inorganics are also third in dollar value behind fertilizers and rubber products, Sun says. In fact, this is one area in which China has enough material to export, sending out of the country about 400,000 metric tons per year of inorganics, especially barium chemicals and manganese products.

Inorganic chemical production, Sun notes, utilizes the most energy-efficient processes available. This can indicate the most modern technology or the most well established, depending on the circumstances. Included among newly imported technology are the Krebs electrolytic process for potassium chlorate from France, a new process for white carbon (a gray-colored industrial carbon useful as an absorbent) from the U.S., and several new processes for the production of granular barium and strontium carbonates from Japan.

The biggest problems plaguing the inorganic chemical industry are underutilization of mineral resources and correspondingly high consumption, the small scale of individual production units, the need for more reliable analytical methods to monitor product quality, and the strengthening of R&D in this often neglected area of production.

Other than fertilizers, highest priority in the new five-year plan of the Ministry of Chemical Industry appears to be given to pesticides for agriculture. This,

New minister of Chinese chemical industry faces number of thorny problems

Gu Xiulian, 52, has replaced Qin Zhongda as the Minister of the Chemical Industry for China. She had previously been vice minister for the State Economic Commission and governor of Jiangsu Province.

Gu's biggest problem will probably be reducing chemical imports, which are blamed for almost two thirds of China's trade deficit. She will also take on the perennial problem of general raw materials shortages that have plagued the country's chemical industry. Another thorny problem is generating more capital for industrial expansion, a problem the chemical industry has in common with every sector of the Chinese economy.

According to *China Daily*, a government newspaper, a new five-year plan is now being formulated by China and it is certain that the chemical industry will be sorely tested during its tenure. Gu won't speculate on the plan but has stated that the first priority of her administration will be to increase the quantity and quality of agricultural chemicals. These are crucial in the battle to feed in excess of 1.1 billion people. The emphasis on agricultural chemicals will probably be of particular benefit to Yunnan, Guizhou, and Hubei provinces, which contain the greatest reserves of nitrogen, phosphorus, and potassium raw materials.

The agricultural chemical industry has already used about $900 million in foreign loans for modernization and has been growing at the rate of about 18% per year for the past 40 years. The hope is that similar growth can be sustained. To this end, Gu is convening national conferences of the numerous research institutes to encourage greater efforts in developing foreign markets that might provide needed external income as well as new technology.

Gu also has been appointed chairman of the China-German Democratic Republic (East Germany) Economic, Technology & Trade Committee, which is seeking to expand trade in Eastern Europe.

Foreign investors in China should prepare for both pluses and minuses of doing business

Although the focus of ACHEMASIA '89 was the chemical industry of China, present and future, a more general look at the investment climate in China was provided by Yang Guanqi, vice president and senior engineer of China International Trust & Investment Corp. (CITIC).

According to Yang, China has been actively encouraging foreign investment in the country since 1979. The policies generally aim at opening up China for investment. There is no expectation by the government, he says, that the policies will change anytime soon.

The past 10 years are regarded as a successful economic period. China has opened a number of special economic zones, has established the guidelines for economic development of the coastal regions, and has set the priorities for foreign investment to favor export-oriented businesses. China has also improved the legal system with respect to foreign economic activity and has provided agencies to coordinate and advise the efforts of potential investors. Most important, the country has devoted considerable capital to the development of the necessary infrastructure to promote investment. Just how successful all this effort may be from the foreign viewpoint is debatable, but there can be little doubt that progress has been made and that more is needed.

The effects of the Chinese efforts to encourage investment are best seen in the results. According to Yang, at the end of 1988, there were about 15,900 foreign joint ventures in China, consisting of 8530 joint equity ventures, 6770 contractual joint ventures, and 594 wholly owned foreign enterprises. The total contracted foreign investment in these ventures is more than $25 billion, of which $9 billion has already been absorbed. Yang says about 85% of these ventures display good operating records with appropriate returns on investment.

Yang characterizes China as the world's largest developing country and believes the country has need of much foreign investment that will aid import substitution—that is, the manufacture of products within China that will decrease the need for imports. Some of the areas of particular interest are energy, raw materials, and intermediate materials. Special priorities are assigned to 160 types of products in 30 categories, including agriculture, chemicals, metals, and minerals.

In considering investment in China, Yang advises the potential investor to give great thought to locating in the coastal areas of China. The intention is to encourage development from east to west in steps. There is also an implicit recognition that the coastal areas contain most of the amenities that most foreign investors would seek.

China has established four special economic zones and 14 coastal cities for special consideration in economic development. The largest is Hainan Province, an island off South China. These designated areas now contain about 80% of the present investment and about 160 million people.

Of particular interest to potential investors are the tax incentives that China provides. The list of incentives is complex and long, but one item that is of special interest is the reduction of the normal corporate income tax of 33% to 15% in the special economic areas and coastal cities and to 24% in other open economic areas. In addition, new ventures whose terms exceed 10 years are exempt from income tax for the first two years and receive a 50% reduction for the next three years.

Probably the most difficult thing for a foreign investor to do is to find a suitable Chinese partner for a joint venture. CITIC and other similar agencies help, but eventually it is a gamble. For most of the major projects involving chemical production, this is less of a problem. Usually company-to-company relations are well along before joint ventures are started.

In the drive to acquire foreign exchange credits, the Chinese have developed currency exchanges in great profusion. Tourists are required, for example, to utilize a special type of currency that trades at a special exchange rate. The government has established 39 currency exchanges in China. In 1988, the total turnover for these exchanges was cited by Yang as about $6.3 billion, which accounted for about one third of the exchange that is represented by foreign joint ventures and about 18% of the total Chinese foreign exchange.

Anyone describing the problems of doing business in China encounters the inevitable horror stories, and even a few happy ones. In fact, the major difficulty in doing business in China is still the language barrier and the confidence that fluency in a foreign tongue provides. The Chinese have established numerous university-level institutes to train their citizens in foreign languages as well as other institutes for teaching foreigners the Chinese language. Although these institutes seem effective, few businessmen take advantage of them. Until they do, doing business in China will continue to generate horror stories.

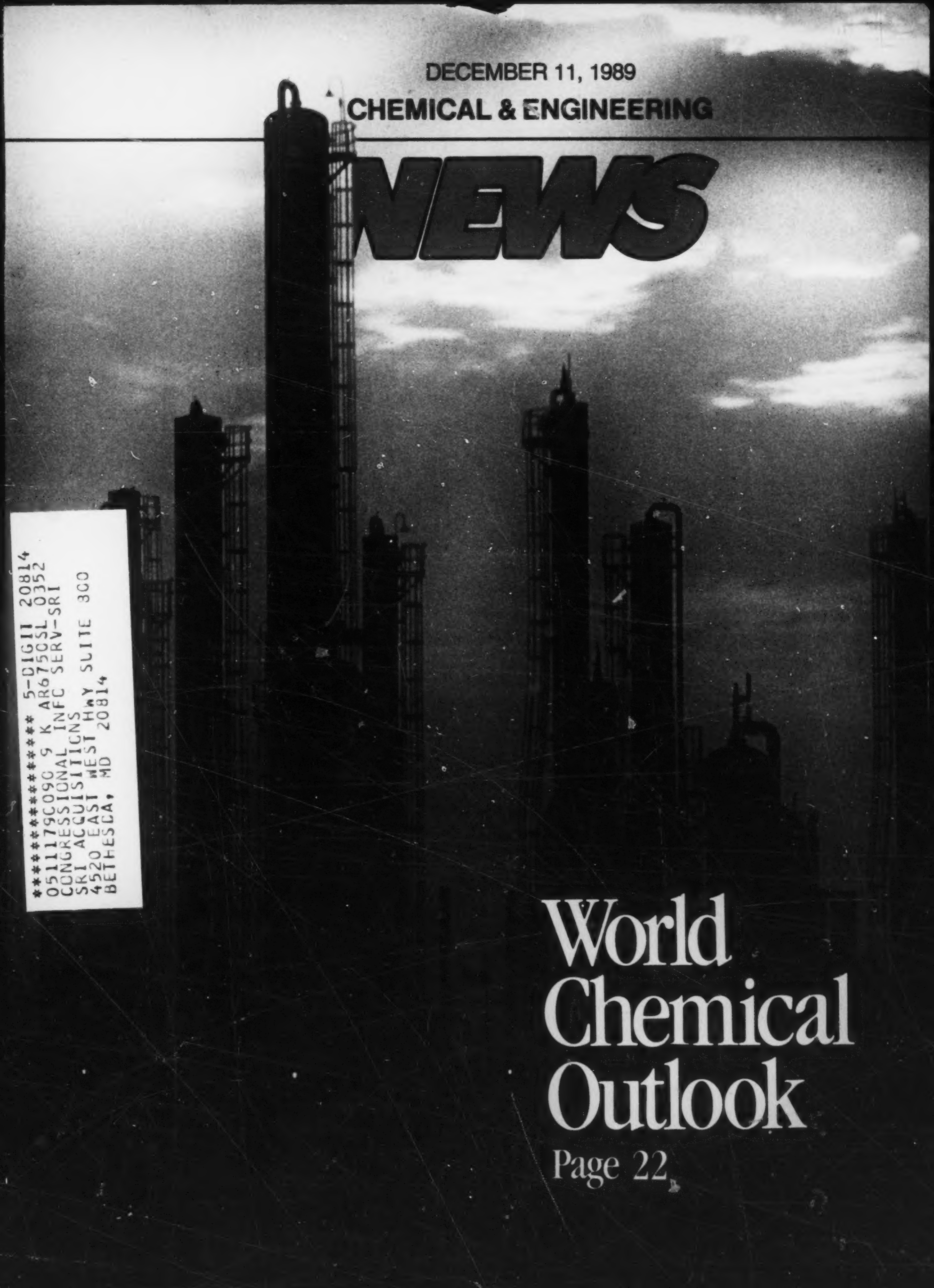
like inorganics, is one of the unusual areas, in that it enjoys a substantial export market. Shang er Cai, director of the information research department of Shenyang Research Institute of Chemical Industry, says the estimated production of pesticides for 1989 will be about 200,000 metric tons. The fraction of this that will be exported is not specified.

Of special pesticide interest is research on natural compounds, which can be used either alone or in combination with the more familiar synthetic pesticides. The Chinese agricultural zones, being primarily subtropical, are subject to a wide variety of pests often unknown elsewhere. Fungi are particular problems.

Whether addressing pesticides or petrochemicals, it is evident that the Chinese chemical industry as a whole has secured a toehold in attacking its problems. Based on the information given at ACHEMASIA '89, it seems China has both the resolve and the capacity to develop a modern chemical industry. □

DECEMBER 11, 1989

CHEMICAL & ENGINEERING NEWS



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World Chemical Outlook

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CHEMICAL & ENGINEERING NEWS

DECEMBER 11, 1989

News of the Week

- **Plan for first five years of program to map and sequence human DNA has been drafted by NIH's human genome committee.** Page 4
- **Cutbacks in chemical weapons were among several major proposals to come out of the Malta meeting between President Bush and Soviet President Gorbachev.** Page 5
- **New method for generating large numbers of monoclonal antibody fragments that could replace present hybridoma technology has been developed by researchers at Scripps and Penn State.** Page 5
- **Du Pont is consolidating its waste treatment and safety operations into a new business, called Safety and Environmental Resources, and expects it to grow into a lucrative endeavor.** Page 6
- **Many federal programs, a number of them science-related, are highly vulnerable to fraud, waste, and abuse, the White House Office of Management & Budget finds.** Page 6

Cover: Photo by Kent Knudson/
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Mobay may enter wastewater treatment business using new system developed by West German parent company, Bayer A.G. **Page 11**

Government

Individual possession, distribution of biological weapons made illegal in recent Senate bill. **Page 13**

Congressional budget compromise gives R&D slight reprieve, sequester order still will have deleterious effects on research funding. **Page 14**

Science/Technology

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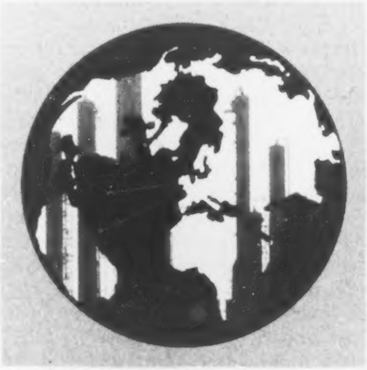
New European environment agency will provide member countries with the information necessary to safeguard the environment. **Page 18**

Caltech launches Linus Pauling lecture series with Pauling himself giving the first annual lecture. **Page 18**

Two-week research visits to Eastern Europe for American scientists are new category added to NAS's exchange programs. **Page 19**



World Chemical Outlook

Growth in demand for chemicals has slowed markedly in the past few months and is now overbalanced by supply. As a result, prices have slumped and producers' profit margins are being squeezed, with the screws likely to tighten even more in 1990. **Page 22**

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LETTERS

CHEMICAL SAFETY

Chlorosulfonic acid and heptane

SIR: Mixing chlorosulfonic acid and alkanes can result in a hazardous situation. Tennessee Eastman Co. experienced the rupture of a weigh tank when heptane was pumped into a tank containing chlorosulfonic acid in an effort to clean the lines and the tank.

The unexpected reaction between heptane and chlorosulfonic acid resulted in the formation of large volumes of gas that ruptured the weigh tank. Experimentation revealed that without agitation, the reaction proceeded slowly (two phases present). Laboratory experimentation also demonstrated that large volumes of gas, primarily hydrogen chloride, were rapidly formed when chlorosulfonic acid and commercial heptane (heptane isomers) were agitated.

A literature search revealed that hydrogen chloride [Jackson, K. E., *Chem. Rev.*, **25**, 67 (1939)] and sulfur dioxide [Gordon, G. S., Burwell, R. L., *J. Am. Chem. Soc.*, **71**, 2355 (1949)] were the reported major gaseous products resulting from the reaction of alkanes and chlorosulfonic acid. An informal poll of coworkers revealed that the reaction of chlorosulfonic acid with alkanes was not common knowledge.

However, the reaction of alkanes with chlorosulfonic acid is briefly mentioned in the third edition of Kirk-Othmer's Encyclopedia of Chemical Technology. Thus, it seems appropriate to share this information with your readers to help prevent the recurrence of this or a similar incident.

John D. Baker
Senior Chemist, Organic Chemicals Division
Development & Control Department
Tennessee Eastman Co., Kingsport, Tenn.

Safety of rubber additives

SIR: A letter by Jerry McLaughlin and Jee Jung (C&EN, July 10, page 3) drew attention to two reports regarding mercaptobenzothiazole (MBT) and raised issues related to human health and safety. MBT is a benzothiazole accelerator used in rubber production and can be found in trace amounts in many rubber-containing products.

The letter cited one study that examined the potential of MBT to cause cancer in laboratory animals [Dieter, M. P., "Toxicology and Carcinogenesis Studies of 2-Mercaptobenzothiazole in F344/N Rats and B6C3F1 Mice," NTP TR 332, NIH Publication No. 88-2588 (May 1988)]. The letter (not the National Toxicology Program report) drew the conclusion that MBT "should not be included in consumer products."

The National Toxicology Program report showed the following:

- Tumors were found in MBT-treated rodents, but the same spontaneous tumor types were found in the untreated, control animals.
- Increased incidence of certain tumors was found in animals of the low dose group but not at the high dose.
- Many of the increased frequencies fell within the range of background incidences of these normally occurring tumor types.
- No consistent trend was found for reductions of time to first tumor incidence.
- No consistent trend was found for progressions from benign to malignant tumor types.
- The study involved lifetime exposures to very high doses, as intended in these worst-case toxicology studies, resulting in reduction in survival, with no clear evidence of carcinogenicity.

When the first three findings occur together in a single study, they greatly weaken the case for carcinogenic potential. The next two findings show a lack of common neoplastic determinants that exist for most established carcinogens, the absence of which casts doubt on the carcinogenic potential of a chemical. The last finding identifies a basic fault in design of the study inasmuch as it indicates that a maximum tolerated dose was exceeded. With this basic fault in design, scientific inference as to the carcinogenic potential of MBT is inappropriate. Although the National Toxicology Program report concluded that there was some, but not clear, evidence of carcinogenic activity, the cumulative weight of evidence outlined above indicates that carcinogenic potential was at best marginal. The National Toxicology Program does not consider the evidence sufficient to include MBT in its annual report on carcinogens, which currently lists over 140 chemicals. For these reasons, any suggestion that MBT should not be included in consumer products on the basis of carcinogenic risk is unfounded. If a compound is found to have some carcinogenic activity, decisions on safety are made on the basis of a more comprehensive risk assessment. In the absence of clear evidence of carcinogenicity, it is inappropriate to propose that a chemical should not be included in a consumer product.

Another conclusion that the letter made regarding the potential for allergy from MBT exposure is far from convincing. The reference cited is a single case

U.S. Polystyrene Demand Growth Holding Below Average

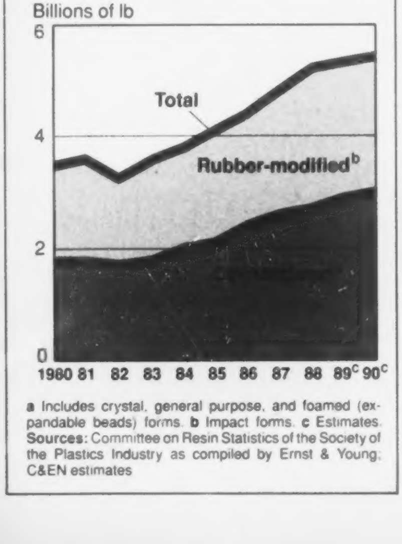
Polystyrene demand growth will continue at 2 to 2.5%, below historical rate, putting pressure on selling prices of most grades through 1990

Bruce F. Greek, C&EN Houston

Current growth in demand for polystyrene—2 to 2.5% per year—in the U.S. is expected throughout next year to remain below the historical average of 3%. The slowing in demand plus new capacity expansions will keep pressure on selling prices for most grades of polystyrene through next year.

Interpolymer competition in packaging has contributed to the slowdown in consumption of polystyrene. Competition from other packaging materials such as paper and paperboard also could cut into the plastic's growth. And another factor could be environmental concerns both about the gases released in the manufacture of polystyrene foam forms and about packaging disposal, especially of fast-food containers. Although recycling is still small, it too could significantly reduce demand for polystyrene in the future.

U.S. polystyrene production growth slowing



a Includes crystal, general purpose, and foamed (expandable beads) forms. b Impact forms. c Estimates. **Sources:** Committee on Resin Statistics of the Society of the Plastics Industry as compiled by Ernst & Young; C&EN estimates

This year U.S. production of polystyrene likely will total 5.3 billion to 5.4 billion lb, up about 2.5% from 1988. This year's expected increase will be about a third of that in 1988, which was up about 8.5% over the previous year. In 1987 and 1988, production growth in polystyrene was double to triple historical growth, raising the decade average. This year and next, lower growth again will bring the average down to about 3%.

World demand for polystyrene will grow an average of 4.6% annually between 1987 and 1993, according to a study completed by DeWitt & Co., Houston. The study reports that world demand increased 6.7% in 1988 to 16.4 billion lb. Global growth last year was below that in the U.S., but it is not expected to slip as much this year and next year as compared with the U.S.'s decline.

By 1993, world demand for polystyrene will total 20 billion lb, according to DeWitt vice president William C. Kuhlke who directed the study. About 85% of the demand will occur in three regions—North America, Western Europe, and the Asia/Pacific area.

World capacity to make polystyrene will grow 4.8% annually between 1987 and 1993, slightly faster than will production, says Kuhlke. By 1993, it will amount to about 22.6 billion lb. Plant operating rates are forecast to decrease modestly until 1991 and then begin a slow rise through 1993.

Polystyrene at a glance

Production: Estimated 1989 U.S. total 5.3 billion lb, up 2.5% from 1988

Capacity: Nameplate at year's end 6.2 billion lb; to increase 10% in 1990

How made: Mass or solution polymerization (polybutadiene dissolved in styrene for impact or rubber-modified grades) and suspension polymerization (mainly for expandable bead forms)

Major U.S. producers: Amoco Chemical, Arco Chemical, Chevron Chemical, Dow Chemical, Fina Oil & Chemical, Huntsman Chemical, Mobil Chemical, Polysar

Price: List 50 cents per lb for crystalline grades to 80 cents per lb for high-impact modified grades

Commercial value: $3 billion for estimated 1989 production

U.S. polystyrene capacity has been rising at a rapid rate this year and is forecast to increase about 10% next year. With completion of some small expansions during this quarter, capacity will reach 6.2 billion lb. The capacity expansions of this year and next are all at existing production sites. No new polymer plants likely will be built in the U.S. until after the early 1990s. This contrasts with the more rapid capacity increases in other parts of the world especially the Asia/Pacific area where a major part of the expansions are at new sites.

U.S. capacity operated this year averaged about 6.1 billion lb. Production through August totaled 3.54 billion lb, according to the Committee on Resin Statistics of the Society of the Plastics Industry as compiled by Ernst & Young. Assuming

World polystyrene demand to hit 20 billion lb in 1993

Region	Billions of lb
Asia/Pacific	6.0
North America	6.0
Western Europe	5.0
Eastern Europe	1.8
Africa/Middle East	0.6
Latin America	0.6
TOTAL	**20.0**

Source: DeWitt & Co.

that output was not reduced appreciably as prices declined this fall, production for all of 1989 may total 5.3 billion lb. Based on these estimates of production and capacity, the average operating rate will slip to about 87% of nameplate capacity, down from about 90% during 1988. Capacity utilization will further drop in 1990 to about 80% of nameplate capacity, unless some capacity is shut down.

Industry sources speculate that some of the smaller and older units of both large and small producers could be shut down during 1990. The older polystyrene plants are inefficient and may lack the refinements to make specialty grades that sell for higher prices. The amount of capacity that will be shut down likely will be small, probably 300 million lb or less. Capacity utilization may then move up less than 3% for the year.

Pressure on selling prices of polystyrene has increased during the fourth quarter, following earlier pressure on those of polyolefins and polyvinyl chloride. By the end of November, selling prices for general purpose crystalline grades had dropped to below 50 cents per lb, down from about 60 cents per lb early in 1989. The effect on other grades of polystyrene has varied, ranging from declines almost as large to negligible ones.

Styrene prices also have been dropping, while benzene prices have increased on both contract and spot markets. Operating problems and maintenance shutdowns at several benzene units (both reformers and toluene dealkylation units) limited benzene production temporarily, according to industry sources. In early 1990, benzene production is expected to recover and prices are likely to drop, particularly on the spot market.

At prices of slightly below 50 cents per lb, polystyrene costs more than polyolefins suitable for similar uses. Polypropylene especially has been taking markets from polystyrene. Large capacity expansions to make polypropylene and rapidly falling monomer costs have triggered the decline in polypropylene's selling prices. The drop in polyolefin selling prices has slowed significantly since the loss of a large part of the U.S. capacity to make high-density polyethylene resulting from the explosion and fire at the Phillips 66 plant in Pasadena, Tex. However, polystyrene prices still are higher than polypropylene prices.

Most of the interpolymer competition for polystyrene occurs in packaging, which accounts for about a third of consumption. Polystyrene for packaging is fabricated by both extrusion and molding. Currently, the major competition occurs in the nonfoamed sheet products—cups, containers for dairy products, and lids (including bottle caps). A significant share of these products use impact-grade polystyrene, which costs more than the general purpose grades. Because of the competition, the nonfoamed uses are forecast to grow more slowly than total polystyrene consumption. Consumption of this form for packaging likely will decline this year and may continue during 1990.

The other major packaging uses require foamed forms, initially fabricated as foamed sheet and expandable beads. These packaging uses account for more than 10% of total consumption and also are expected to grow more slowly than total use. The major consumer products of foamed sheet polystyrene are trays for meat and produce, egg cartons, and containers for various kinds of other processed food. Because many of these containers are consumer items, environmental concerns could affect their use more quickly than other packaging products and could limit growth. Antiplastics sentiment likely will have more effect than interpolymer competition, leading to substitution by paper packaging and dampening growth for these uses of polystyrene.

Building and construction, at about 10% of the total, is a relatively distant second in the markets for polystyrene. More than 80% of construction use is in insulation board, made either of foamed polystyrene or expandable beads and often laminated with other materials. Although the variations in volume of construction affect demand, the average growth for this use is forecast to be greater than for all uses of polystyrene.

Appliances and consumer products, slightly smaller than the construction market, also account for about 10% of polystyrene consumption. The appliances market (largely cabinets for various electronic items and parts for refrigerators) has been spotty for polystyrene, depending on changes in styles and on new components as well as on competition from polypropylene.

Polystyrene also has been seeing increased competition for consumer products made from polypropylene; such products are price-sensitive in many of their markets. Redesign of some appliance components may allow polystyrene to replace acrylonitrile-butadiene-styrene, which would offset some of the demand lost to polypropylene. If polystyrene prices decline further, making it more competitive, these uses will continue to increase faster than average.

Other applications and exports likely will grow at about 2.5% next year. Some specialized uses, such as medical and laboratory devices, may grow above average, but will be offset by other slower growing uses, which include such products as small items for office use, various kinds of knobs and handles, and louvers and other parts for lighting fixtures. Use of polystyrene in several types of plastic alloys and blends with various other polymers has slowed but could increase as new products are developed.

Exports of polystyrene likely will exceed imports by more than 275 million lb this year, far above the less than 150 million lb of 1988. But such a level is unlikely to hold because of added capacity being built in other parts of the world. □

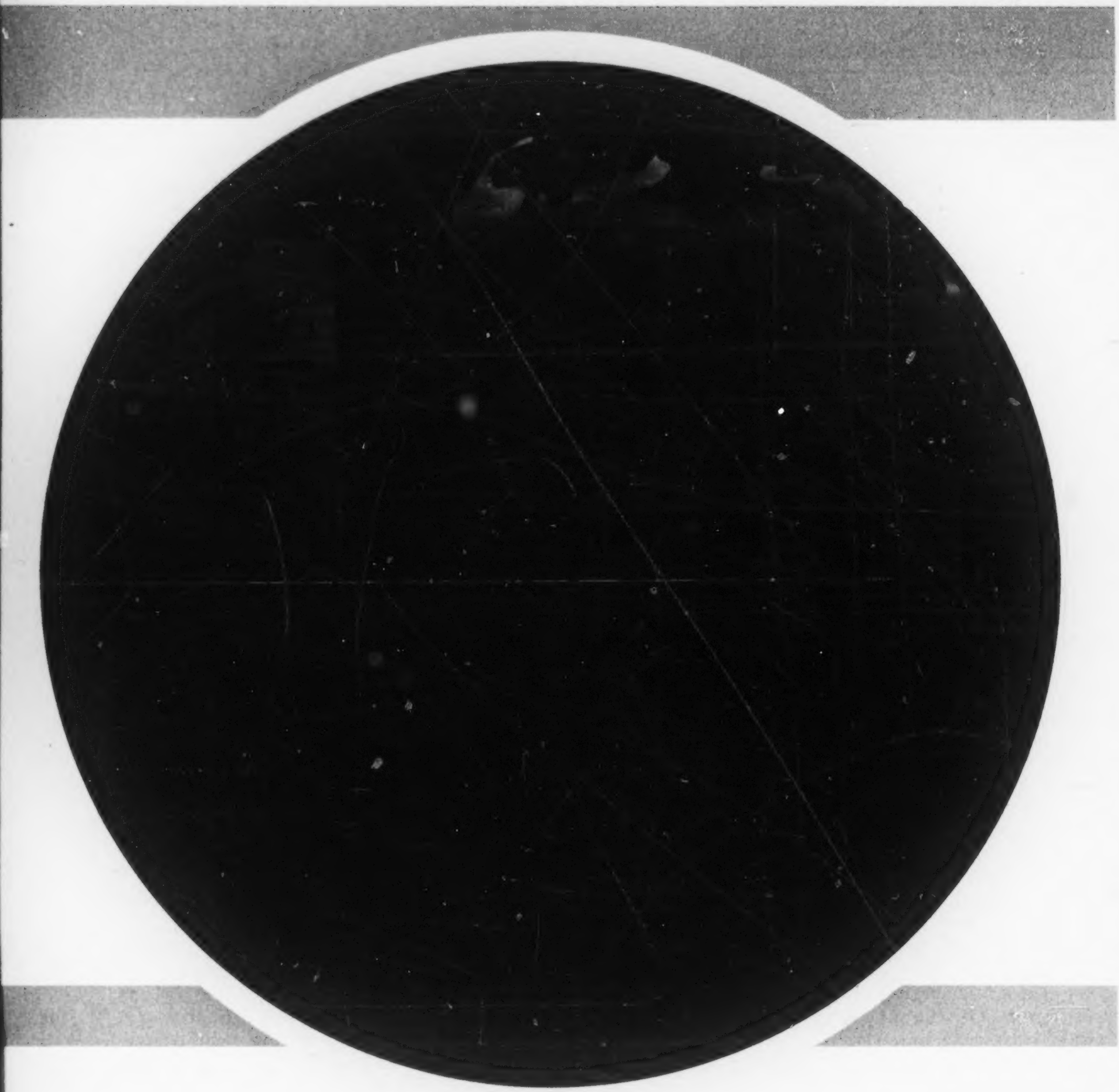
World Chemical Outlook

After two or three years of extraordinarily favorable conditions for producers of chemicals, the business climate this year has become markedly different.

At the start of 1989, the economies of the industrialized western world were all strong. Customers' appetite for chemicals and the products made from them seemed insatiable. Chemical firms were running their plants full out and still not meeting market demand. They were in the enviable position of being able to mark up prices with ease, even though feedstock costs were relatively low. Not surprisingly, therefore, profitability in the chemical industry was surging.

Now, as 1990 makes its entrance, economic growth seems to be easing. At the same time, plant capacity has been building up. Consequently, supply of many petrochemicals, as well as plastics and other derivatives, has overtaken demand. Competition in the global marketplace has become more cutthroat once again.

In the U.S., many chemical companies, especially those whose business is focused on commodity products, have been forced to cut prices drastically in recent months to maintain market share. Profits, not surprisingly, have weakened significantly. Although export business remains brisk, the word from Western Europe, Japan, and Canada is much the same.



Business still looks sound for much of the chemical industry, to be sure, such as specialty chemicals or pharmaceuticals and other consumer items. And economic forecasts generally look for continued expansion during the year ahead, although at a slower pace than recently. So hardly anyone in the industry really expects the early 1990s to reprise the early 1980s. But to avoid that, industry executives will be facing some tough decisions during the year ahead.

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Competition heats up as demand for chemicals cools

Prices are sinking and a shift from a seller's to a buyer's market is putting the profits of U.S. chemical makers in jeopardy

David M. Kiefer
C&EN Washington

Déjà vu, all over again, for the U.S. chemical industry? The evidence is by no means yet clearcut. But demand has been slack during the past six months for many big-volume petrochemicals and their derivatives. At the same time, production capacity has been building up rapidly. Not surprisingly, selling prices have tumbled. All of which has an unnerving resemblance to business conditions seven or eight years ago, when the chemical industry was sorely pressed by too much output chasing too few customers.

Selling prices for industrial chemicals have slumped 5 to 6% since they peaked last May, government figures indicate, and now are about 1% lower than they were a year ago. For plastics, current prices are even more depressed—down more than 10% since hitting a high early last spring.

Are the economic developments of this year's second half indeed a harbinger of an impending cyclical downturn for the chemical industry, similar to the one that wracked it in the early 1980s? Already, industry earnings are again clearly under pressure. For producers of basic chemicals as a whole, profits were down about 15%, compared with 1988, during this year's third quarter. Comparison between the current three months and last year's like period is likely to be even less favorable.

But the shape of 1989's chemical industry differs significantly from that of 1981 and 1982. For one thing, after the sweeping restructuring and retrenching undertaken by many chemical producers following the last recession, the industry's cast of characters now has changed considerably.

Many of the companies that dominated the industry a decade ago—such as Du Pont, Dow Chemical, and Monsanto—still do so. But not in the same way. They are much more diversified now, much less dependent on commodity chemicals and plastics products for sales and earnings. Pharmaceuticals and other consumer items, as well as specialty materials like pesticides, play a much bigger role. The goal was enhanced growth, higher return on investment, and greater earnings stability.

The strategy may be working. Look at Monsanto, for example. It has undergone perhaps the most dramatic shift in product focus of any of the leading chemical firms; it managed to lift this year's third-quarter net income 9% from a year earlier, with a big part of the gain a function of improved results from pharmaceuticals, its Nutrasweet artificial sweetener, and industrial controls. Widely diversified Du Pont likewise chalked up higher third-quarter earnings this year. And although Dow's earnings were off 7% from a year ago, they would have looked a lot worse were it not for strong results from its expanding consumer specialties operations.

Likewise, many of the smaller old-line chemical companies, those whose business is focused on specialty products, continue to fare remarkably well. Third-quarter earnings for companies like Crompton & Knowles (up 47% from the year before), Loctite (up 21%), Nalco Chemical (up 21%), and Great Lakes Chemical (up 18%), all suggest continued strength for products sold into narrowly targeted end-use markets. The financial performance of some of these companies, of course, at the same time is benefiting from recent markdowns in the prices of many of the petrochemical intermediates they buy.

On the other hand, companies that are tied still to commodity chemicals—many of them relative newcomers to the industry that picked up plants for making petrochemicals and polymers when they were shucked off by several of the leading chemical and petroleum operators during the mid-1980s—are the ones who are bearing the brunt of recent oversupply and price weakness.

Thus, third-quarter profits for Aristech Chemical nosedived 47% from the year-earlier period, primarily because of price erosion and an unsettled export market for polypropylene. Turmoil in the polypropylene market also is largely responsible for the 71% slump in Himont's third-period earnings.

B. F. Goodrich's net from continuing operations fell 43%; company chairman John D. Ong explains that for polyvinyl chloride "industry capacity has overtaken demand," prices have dropped, and that some time may be required to bring supply and demand back into balance. Quantum Chemical's profits plummeted 79% (before factoring in the cost of two plant fires and a special accounting charge), reflecting lower sales and narrowing profit margins in its polyethylene operations. And shrinking profit margins for styrene and polystyrene operations cut into Huntsman Chemical's earnings.

Clearly, producers of petrochemicals and plastics no longer are harvesting the bountiful profits of the past two or three years. And a glut in capacity for producing olefins and their derivatives is a definite threat that will be hanging over the industry not only next year but throughout the early 1990s.

Whether the downturn in earnings for petrochemical and plastics producers worsens and spreads more widely throughout the overall chemical industry hinges largely on the health of all the nation's business. And lately, the national economy has been wheezing.

During the 12 months through this past September, real gross national product has grown nearly 3%, with the three months ending with September alone registering an annual rate of growth of 2.7%. That's a better showing than most economists had forecast would be the case 12 months ago. Nevertheless, signs of increasing turbulence in the current business climate are becoming more plentiful. Industrial production has been relatively flat since last spring. Growth in consumer spending is slowing. And fewer new jobs are opening up now than a year ago.

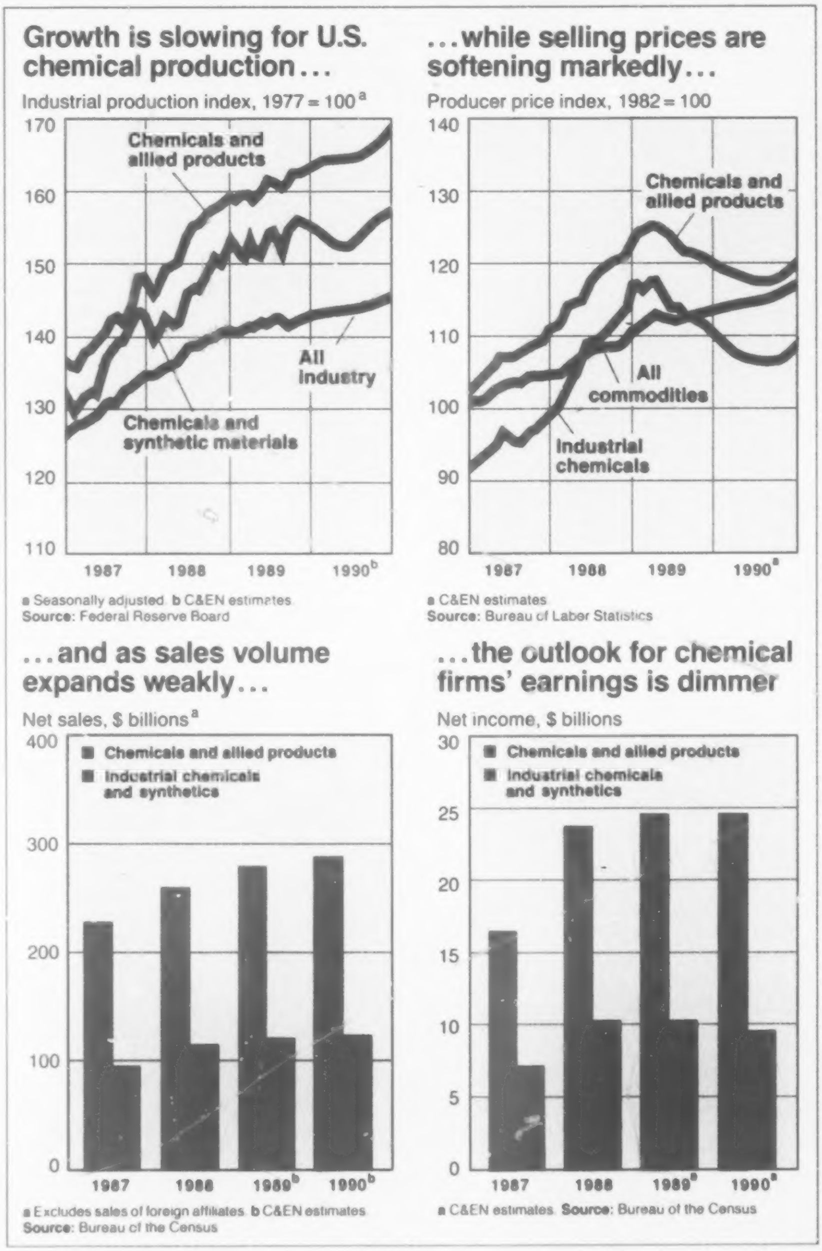
Economists generally expect 1989's final three months will show distinctly slower growth in GNP, with the quarter-to-quarter increase perhaps dwindling to an annual rate of close to 1%. That would mean that expansion of GNP for all of 1989 will be nearly 3%, compared with nearly 4.5% the year before.

The consensus of economic opinion now is that GNP will continue to edge higher again in 1990, probably at an annual rate no greater than 1.5 to 2.5%. But the majority of business economists are still betting on the much-heralded "soft landing" for the U.S. economy. They also seem firmly convinced that the U.S. will work its way through another year without experiencing an actual downturn in the business cycle.

It also is widely conceded, however, that whatever further growth in GNP occurs next year will be largely driven by the service industries, rather than manufacturing. And that is not a particularly cheerful prospect for chemical producers, whose customers are located throughout all U.S. manufacturing activity. Moreover, some of their best customers, such as the automobile industry and home builders, are the ones who now seem most at risk.

The number of new housing units started has been falling month by month during nearly all of 1989, sinking to the lowest level for any month in about seven years last September. For the whole year, housing starts probably will total nearly 1.4 million, down 6% from last year. Lower interest rates on mortgages are likely to encourage home buyers, but high prices on new homes are a strong offset. Although home builders are hopeful that the decline in the housing market may now be bottoming out, they do not really expect housing starts to increase appreciably next year.

Automobile producers seem to be



Growth is slowing for U.S. chemical production . . .

a Seasonally adjusted. b C&EN estimates.
Source: Federal Reserve Board

. . . while selling prices are softening markedly . . .

a C&EN estimates
Source: Bureau of Labor Statistics

. . . and as sales volume expands weakly . . .

a Excludes sales of foreign affiliates. b C&EN estimates.
Source: Bureau of the Census

. . . the outlook for chemical firms' earnings is dimmer

Net income, $ billions
30
25
20
15
10
5
0
Chemicals and allied products
Industrial chemicals and synthetics
1987
1988
1989[a]
1990[a]

a C&EN estimates. **Source:** Bureau of the Census having an even tougher time persuading consumers to buy their new models. Car sales slumped drastically this past October and November from the year before. Consequently, car makers have cut back production to the lowest level since late 1972, laying off workers and shutting down assembly lines. This year, production is likely to drop below 7 million cars, down 3% from last year. Truck production, which has generally held up better than car output, also will not quite match last year. The auto industry is girding for slower sales again in 1990, perhaps down 5% or more from this year's level of nearly 15 million cars and trucks. That portends an even greater falloff in U.S. production.

Other industries also are likely to provide less buoyant markets for chemical products. Shipments of major home appliances are little changed this year from 1988, and probably will drop 2 to 4% next year, for example. And production of paper and paperboard is rising more slowly and will increase only about 1% this year, compared with a 3% gain in 1988.

Assuming the U.S. economy does indeed achieve a soft landing next year, C&EN estimates that production of basic chemicals and synthetic materials, ahead nearly 6% this year, will be essentially unchanged in 1990, give or take a percentage point. Prices of industrial chemicals, meanwhile, probably will continue to fall, at least during the early months of the year. For all of 1990, they are likely to be down about 6% on average, on the heels of a 7 to 8% increase this year that reflects rapid increases last winter and spring.

This is a scenario that spells trouble for basic chemical producers' earnings statements. This year, a relatively strong first half is being balanced by decidedly poor results in the final six months. The year as a whole, therefore, will be pretty much a standoff, with net income for the industry overall about unchanged from 1988. For many companies whose basic chemicals business has not been cushioned by diversification into consumer or specialty chemical lines, moreover, profits will be below those of last year. Next year, C&EN forecasts profits for basic chemical companies will decline, perhaps 7 to 12%.

For other segments of the broad chemical business, however, the outlook is largely still upbeat, barring an outright recession. Specialty chemical firms will have a solidly profitable year in 1989 and probably will ring up at least moderate further gains in 1990. Pharmaceutical companies, too, are still on a roll, thanks to a steady stream of hot-selling and high-margined new products that they have been introducing during the past few years. Fertilizer makers, who were plagued by severe price erosion this year, also are more optimistic about the year ahead, in light of prospects for rising crop plantings and high farm income.

Even the relatively bleak prospects for producers of basic chemicals should be viewed in perspective. For them, the past couple of years have been exceptionally good—a hard act indeed to follow. Unless the recent downtrend accelerates, which few in the industry now expect, their selling prices next year will still average comfortably above those of two or three years ago. And profits in 1990 are likely to be eclipsed only by those for this year and last—and will be nearly double those of just three years ago. □

Output edges lower for many of the chemical industry's big-volume products

	1987	1988	1989	1990
INORGANIC CHEMICALS				
Thousands of tons unless otherwise indicated				
Ammonia	16,095	16,937	17,100	17,400
Chlorine gas	11,019	11,330	11,100	10,700
Hydrochloric acid	2,869	2,834	2,750	2,500
Nitric acid	7,225	7,887	7,950	7,900
Oxygen, billions of cu ft	403	449	460	450
Phosphoric acid	10,685	11,729	11,700	11,900
Sodium hydroxide	11,486	11,985	11,900	11,600
Sulfuric acid	39,235	42,775	43,700	44,000
ORGANIC CHEMICALS				
Millions of lb unless otherwise indicated				
Acetic acid	3,246	3,159	3,400	3,200
Acetone	1,846	2,303	2,350	2,300
Acrylonitrile	2,452	2,609	2,850	2,800
Benzene,[a] millions of gal	1,576	1,588	1,600	1,550
Butadiene	2,931	3,169	3,100	3,100
Caprolactam	1,156	1,261	1,250	1,200
Cumene	4,105	4,455	4,400	4,250
Cyclohexane	2,276	2,297	2,300	2,150
Ethylene	34,951	37,204	35,500	35,000
Ethylene glycol	5,183	5,517	5,600	5,300
Formaldehyde	5,733	6,280	6,200	6,000
Methanol	7,537	8,142	7,900	7,500
Phenol	3,351	3,562	3,500	3,500
Phthalic anhydride	1,035	999	1,020	980
Propylene	19,019	21,224	21,000	19,800
Styrene	8,014	8,984	8,300	8,100
***o*-Xylene**	940	971	850	780
***p*-Xylene**	5,155	5,601	5,700	5,600
PLASTICS				
Millions of lb				
Polyethylene, high density	7,995	8,399	8,050	7,800
Polyethylene, low density	9,599	10,398	9,300	8,900
Polypropylene	6,647	7,272	7,350	7,300
Polystyrene	4,780	5,130	5,100	4,900
Polyvinyl chloride	7,971	8,350	8,450	8,500
SYNTHETIC FIBERS				
Millions of lb				
Acrylic and modacrylic	592	588	550	530
Nylon	2,690	2,669	2,700	2,600
Olefin and vinyon	1,494	1,568	1,650	1,680
Polyester	3,540	3,680	3,650	3,550

[a] Petroleum refiners only. **Sources:** Bureau of the Census, International Trade Commission, Society of the Plastics Industry's Committee on Resin Statistics, Fiber Economics Bureau, C&EN estimates (for 1989 and 1990)

Foreign Trade

Export markets remain strong for U.S. chemicals

With exports of chemicals rising twice as fast as imports, trade surplus hits record $16 billion

Earl V. Anderson
C&EN Northeast News Bureau

If all U.S. trade were like its chemical trade, the Administration and Congress wouldn't have to struggle with a lingering and burdensome balance of trade deficit. That overall trade deficit—happily—will decline again this year, if only slightly. But at an estimated $110 billion, it is still uncomfortably high.

The U.S. chemical balance of trade, meanwhile, is very much in the black. In fact, it will soar to a new record surplus of $16.4 billion this year.

The U.S. chemical industry's trade performance is nothing short of a marvel. World trade in chemicals, measured as exports, likely will increase only 6% in 1989, following two successive years of gains of 20% plus. But chemical exports from the U.S. probably will be up a hefty 17% to $37.7 billion, higher than ever before. That performance will propel the U.S. share of world chemical exports up 1.4% to 14.8%.

U.S. chemical imports will also increase—to a record $21.3 billion. But that will be only a 7% gain, which is pretty much in line with the overall growth of worldwide chemical trade.

Stronger growth in exports than in imports is also reflected in the overall U.S. trade picture. For the third successive year, U.S. export growth will outpace that of imports. Exports are likely to advance 13% to $365 billion, while imports will be up only 8% to $475 billion.

This lopsided growth will be enough to pare the trade deficit from $119 billion in 1988 down to $110 billion this year, the lowest it has been since 1984. But it's still too high to satisfy many international economists, who believe that the U.S. trade deficit, coupled with its budget deficit, ranks alongside developing countries' massive debt as one of the world's major economic problems.

The fact that U.S. exports, including chemical exports, are outpacing imports this year is something of a paradox, as far as currency exchange rates are concerned. A strong dollar hurts exports by making them more expensive and therefore less competitive in foreign markets. It also makes imports less expensive and better able to compete in the U.S. against domestic products.

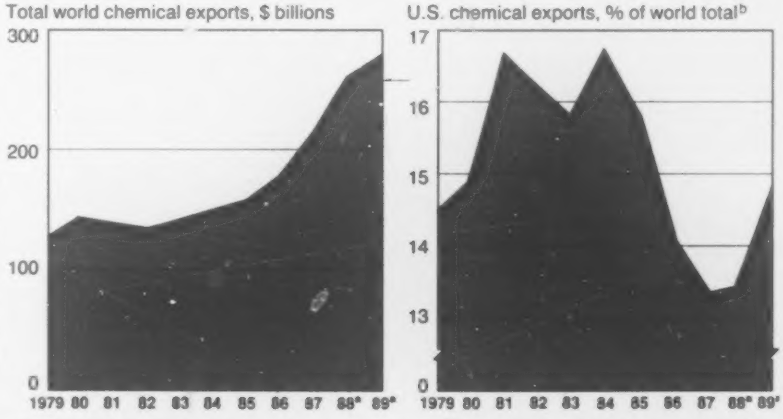
A weaker dollar does just the opposite. It helps exports and hurts imports. That is why, after the dollar started falling from its record peak in 1985, the U.S. trade deficit started falling, from its high of $153 billion in 1986.

This year, however, the dollar has recovered some of its lost strength. By midyear, it was up more than 20% against the Japanese yen and British pound and 16% against the West German deutsche mark.

Since June, the dollar has weakened somewhat against the major foreign currencies, but it is still higher against most of them than at the end of 1988. At the end of November, for instance, the dollar stood at 143 yen, up 16% for the year. It was also up 17% against the

Growth in global chemical exports moderates . . .

. . . while U.S. share of total improves a bit



a C&EN estimates. b Defined as U.S. chemical exports as percentage of world chemical exports less U.S. chemical imports.
Sources: United Nations, Organization of Economic Cooperation & Development, European Community, Japanese Ministry of International Trade & Industry

Organic chemicals and plastics lead another surge in U.S. chemical exports

$ Millions	U.S. chemical exports 1989[a]	1988	1987	1986	U.S. chemical imports 1989[a]	1988	1987	1986
Organic chemicals	$11,220	$ 9,381	$ 7,550	$ 6,293	$ 7,457	$ 6,953	$ 5,408	$ 4,704
Plastics and resins	8,155	7,277	5,492	4,301	3,417	2,433	1,987	1,837
Medicinals and pharmaceuticals	3,663	3,941	3,182	3,090	2,134	1,859	1,456	1,240
Fertilizers, manufactured	3,008	2,498	2,259	1,935	1,060	1,021	795	865
Inorganic chemicals	3,001	2,702	2,122	1,771	2,318	2,498	2,030	1,894
Radioactive materials	1,611	868	1,017	1,302	786	1,098	1,012	1,382
Pesticides and disinfectants	1,163	910	732	664	217	577	398	580
Flavors, perfumes, cosmetics, and toiletries	1,024	709	579	488	978	932	796	679
Pigments, paints, and varnishes	663	449	411	333	527	395	427	348
Cleaning and polishing materials	407	395	357	302	206	260	205	214
Dyeing, tanning, and coloring materials	312	258	217	174	595	610	621	487
Explosives and pyrotechnics	117	91	91	81	128	118	110	111
Miscellaneous	3,306	2,821	2,382	2,032	1,427	1,122	968	660
TOTAL	**$37,650**	**$32,300**	**$26,381**	**$22,766**	**$21,250**	**$19,876**	**$16,213**	**$15,001**

a C&EN estimates. **Source:** Bureau of the Census

British pound at 0.64 pound per dollar and up 2% against the mark at 1.79 marks per dollar.

Theoretically, this trend in dollar exchange rates should have hurt U.S. exports and given a boost to imports. But theory doesn't always hold true in world trade. Exactly the opposite is happening this year.

One reason is the time lag, or J-curve, as economists refer to it. Exports and imports don't respond immediately to changes in currency exchange rates. It may take many months—even years—for changes in exchange rates to have an impact on trade.

Jeffrey A. Rosensweig, professor of international business and finance at Emory University's business school in Atlanta, Ga., says that this year's rise in the dollar is too recent, too moderate, and perhaps too temporary to disrupt the trend toward slowly improving U.S. trade balances. He believes that this year's U.S. trade patterns are still responding to the fairly low dollar values of 1988.

U.S. exports also may be rising faster than imports because the U.S. economy is cooling off. A weaker economy tends to create less demand for imports, while still-strong economies overseas are acting as a magnet for U.S. exports.

As usual, economists disagree about what will happen to the U.S. trade balance next year. Some say that the trade balance will deteriorate in 1990. Others believe that it will improve, perhaps dropping to below $100 billion. That's a level it has not seen since 1983.

If a weaker dollar does, in fact, help at all, then the dollar is heading in the right direction. Many currency traders believe that the dollar's recent decline will continue into next year. One reason is that they expect interest rates in the U.S. to move lower as the Federal Reserve Board tries to keep the economy from sliding into recession.

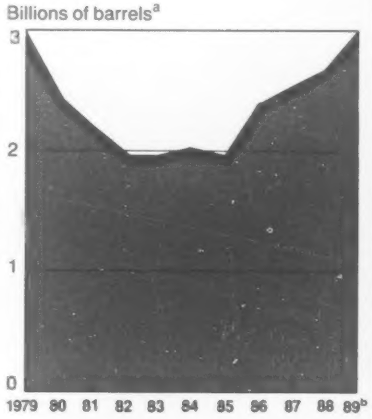
Another is that some interest rates abroad are expected to rise, particularly in West Germany and Japan. Falling interest rates tend to weaken a currency, whereas rising rates tend to strengthen it.

On the other hand, if falling interest rates stimulate the U.S. economy too much, they could trigger a stronger demand for imports. And higher interest rates overseas could dampen economic growth enough to put a crimp in demand for U.S. exports. Neither of these developments would bode well for the U.S. trade balance.

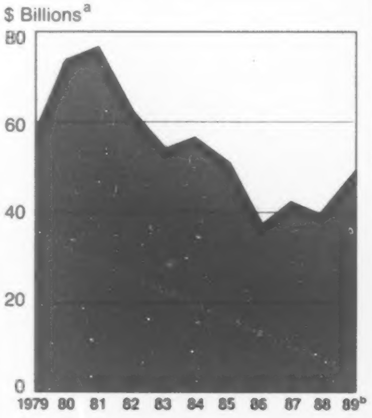
U.S. trade fortunes in the coming year, then, will depend heavily upon how adept the world's finance ministers are at balancing interest rates, exchange rates, and economic growth rates. And that's something that's virtually impossible to predict.

Whether the trade balance improves or worsens next year, most

Rise in volume of U.S. oil imports...



...plus higher prices up U.S. import bill



a All petroleum products. b C&EN estimates.
Source: Bureau of the Census

Total U.S. exports bolstered by growth for chemicals and other manufactured goods

$ Billions	U.S. exports 1989[a]	1988	1987	1986	U.S. imports 1989[a]	1988	1987	1986
Chemicals	$ 37.7	$ 32.3	$ 26.4	$ 22.8	$ 21.3	$ 19.9	$ 16.2	$ 15.0
Machinery and transportation equipment	147.6	135.1	108.6	95.3	206.4	197.0	177.8	161.6
Other manufactured goods	59.8	47.3	36.5	30.6	138.9	131.9	118.6	105.5
Crude materials (inedible) other than fuels	27.2	25.1	20.4	17.3	15.9	13.4	11.5	10.4
Mineral fuels, lubricants, and related materials	9.4	8.2	7.7	8.1	52.6	41.1	44.2	37.3
Food and live animals	30.3	26.4	19.2	17.3	21.4	20.1	20.5	20.8
Beverages and tobacco	5.2	4.5	3.7	2.9	4.1	4.1	4.1	3.9
Animal and vegetable oils and fats	1.4	1.5	1.0	1.0	0.8	0.8	0.6	0.5
All other products	32.4	27.5	20.4	11.0	13.6	12.6	12.4	14.9
TOTAL	**$365.0[b]**	**$322.4[b]**	**$252.9[b]**	**$217.3[b]**	**$475.0**	**$440.9**	**$405.9**	**$370.0**

a C&EN estimates. b Includes reexported imports (not included in individual product categories). **Source:** Bureau of the Census

economists agree that the movement will be small. They also agree that the U.S. trade balance would be significantly better were it not for the much higher bill that the U.S. is paying for imported oil.

This year, U.S. importers will shell out about $48 billion for foreign petroleum and petroleum products. That's 25% higher than last year, even though the volume of oil imported will rise only 9%. The reason, of course, is that the average unit price of imported oil will top $16 per barrel this year, while it was just slightly over $14 per bbl in 1988.

Little letup is in sight for this higher level of oil imports. According to the American Petroleum Institute, imports of crude oil and petroleum products in October averaged 8.2 million bbl per day, compared with 7.8 million in October 1988. This is despite the fact that oil consumption in the U.S. is declining.

What is also declining, however, is domestic crude production. As a result, imports now account for almost half of U.S. consumption. Not surprisingly, some energy experts fear that the stage is being set for another oil crunch in the U.S.

The U.S. chemical industry has no such trade problems. It established a new record surplus in its trade balance last year. It will easily top that record this year. And, in all likelihood, the industry will set still another record trade surplus in 1990.

Estimating next year's chemical trade performance is little more than a guessing game. But most guesses are centering on a 6 to 8% improvement in both chemical exports and chemical imports. If this is correct, U.S. chemical exports will come close to or exceed $40 billion for the first time. The chemical trade surplus, which likely will hit $16.4 billion this year, probably will top $17 billion and could surpass $18 billion in 1990.

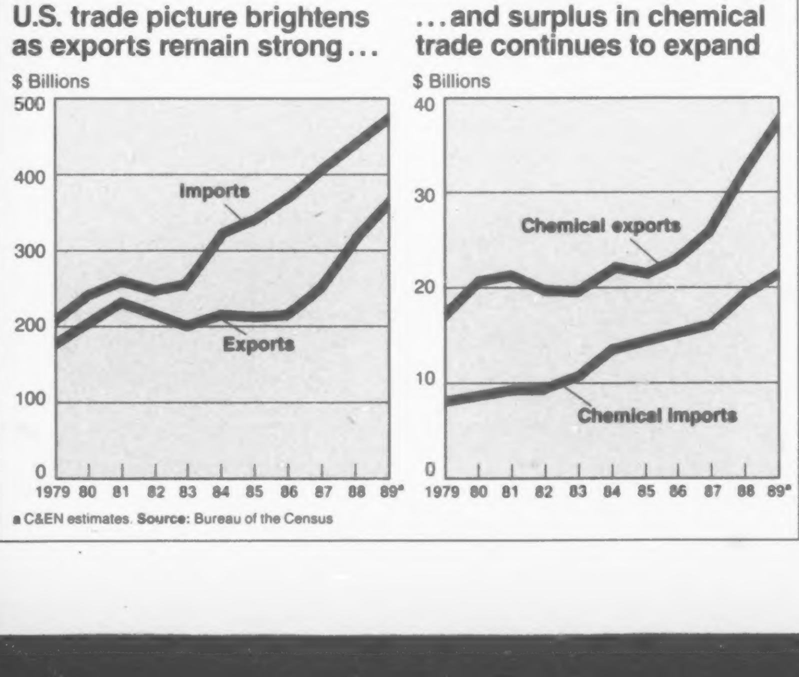
To rise this way, U.S. chemical companies must continue getting strong performances from their export heavyweights—organic chemicals, plastics, pharmaceuticals, and fertilizer. Together, these four categories account for almost 70% of U.S. chemical exports.

Organic chemicals and fertilizer are both having strong years on export markets in 1989. Both will end the year with a gain of about 20%. Pharmaceuticals and plastics, however, are a different story.

Pharmaceutical exports will decline this year. Plastics exports are increasing, but are likely to gain only 12% over 1988 to $8.2 billion. That wouldn't be bad were it not for the fact that plastics imports probably will increase 40% to $3.4 billion.

This surge in plastics imports means that the huge trade surplus in plastics will actually decline from $4.8 billion to $4.7 billion. This will result in the first drop in the plastics trade surplus since 1985.

Plastics trade statistics, however, may be misleading. The government has changed its reporting system since the first of the year, when the U.S. converted to the harmonized tariff system. As a result, statistics on plastics exports and imports for 1988 and 1989 may not be directly comparable. ☐



a C&EN estimates. **Source:** Bureau of the Census

Western Europe

Optimism prevails although a mild downturn is likely

Prices are lower and chemical firms look for slower growth in demand but no recession next year

Patricia L. Layman
C&EN London

According to Hans Albers, chairman of West Germany's BASF, "The slower growth rates that we have long predicted have now become reality, but there is no reason for pessimism. The chances for business conditions to remain favorable in 1990 are very good." Speaking at a BASF press conference in Ludwigshafen late last month, Albers forecast that 1990 won't be bad at all. And coming after 1989, that is saying quite a bit.

For the chemical industry in Western Europe, 1989 was a remarkable year—a year, in fact, when management throughout the industry came to grips with a most welcome blessing: good times.

It's not that 1989 just ushered in an upturn in business. The year saw chemical production grow roughly 4% from 1988, which had been generally acknowledged as the all-time best year for the petrochemical industry. In 1988, chemical production in Western Europe was up 7% over that in 1987, which itself had been, in turn, a particularly good year. Moreover, in 1988, profitability was extraordinarily high, as surging demand pushed capacity utilization to its upper limits for many products, with resulting firm selling prices and high profit margins.

This year, chemical company managements are looking ahead optimistically for sales growth, for higher investment, and for serious strategic planning. Now, 1990 is shaping up as the year of hitting stride in West Europe's chemical industry. Forecasters agree that a downturn must come eventually—but not this coming year.

According to the Brussels-based European Chemical Industry Federation (CEFIC), nearly all of the chemical industries of its member countries still see growth ahead in chemical output during 1990. Last year, CEFIC forecast that overall chemical production would be up about 3% over 1988; actual growth will be closer to 4%. Now, CEFIC is predicting that overall growth in chemical output next year will match that 4%. Says Hugo Lever, CEFIC's general director, "We believe any recession will be quite a mild one. There will not be a tremendous dip."

In fact, Lever is being particularly cautious—most chemical companies are not forecasting recession at all for 1990. A slowdown in growth, perhaps, but no actual decrease in production.

Whatever happens in 1990, of course, will reflect roughly the same conditions that influenced business performance in 1989, just as 1989 followed from 1988. Prices were at an all-time peak in 1988 for many commodity chemicals, points out Neville Pinnington, senior division head for bulk petrochemicals at Shell International Chemical in London. But in 1989 the more extravagant prices came back down. Such prices were so high they were unstable, and such conditions could not last. It was inevitable for prices to fall. A similar point was being made by nearly all company officials all through the year.

It was perhaps surprising, in fact, that the year turned out as well as it did. Say economists at ICI, the British chemical giant, "Overall economic performance in the European economies has in total been rather better than expected a year ago." Their counterparts at BP Chemicals add, "The principal driving force has been the high level of investment and buoyant international trade."

Sometimes, general economic conditions benefited the chemical industry through 1989; sometimes they hindered it. Fluctuation of the U.S. dollar, for example, was a two-edged sword. Many of the industry's feedstocks are priced in dollars; as the dollar appreciated in value during the first half of the year, feedstocks became relatively more expensive to buy with European currencies.

Rising feedstock costs hurt downstream production economics, with "serious repercussions," as an executive with Italy's Montedison puts it. On the other hand, sales transacted in dollars—by U.S. subsidiaries, for example—become worth more in the home currency, adding nicely to total sales volume. Montedison first felt this impact in its pharmaceuticals business and then at its Himont subsidiary. Other companies with significant sales in North America, such as the Netherlands' Akzo and ICI, report a similar benefit.

Of course, there is the other side of the coin. Foreign subsidiaries of U.S. companies see their sales and profits shrink when translated back into U.S. dollars when the dollar is strong. What the subsidiaries have to look to, says L. Blaine Boswell, president of PPG Europe, the European arm of PPG Industries, is that there is a good balance, within the country in which they are operating, between production costs and selling prices.

There is no denying the fact that prices throughout the chemical industry have dropped. One of the major reasons, believes Shell's Pinnington, is that since about the end of 1988 China—which had been buying significant quantities of petrochemical products—abruptly ceased doing so. One China-watcher says the decentralizing decisions within the country earlier in the decade had allowed for fragmented, uncoordinated purchasing, with no controlling hand watching hard-currency supplies. The country overpurchased, ran out of hard currency, and stopped buying.

That abrupt action, in turn, had a snowball effect. Exporters who had been selling to China found that market shut off, so they turned more aggressively to their local markets, unsettling prices. "As prices fall, people destock," says Pinnington, in turn putting more pressure on prices. Buyers put off buying because they think that prices will continue to fall, and they also don't buy because they think their competitors also will put off buying.

The resulting price declines across the petrochemical industry have kept pressure on the Western European chemical industry to continue the restructuring and rationalization it had begun in the mid-1980s. Lower prices perhaps also have brought some investment planners back down to more solid ground from the blissful peaks of 1988. And that, in turn, might help prevent the chemical industry from embarking on another round of overcapacity.

Says one industry observer, "It's really not a bad thing that prices have come down. We have had good times long enough that people were beginning to forget the past. For newcomers to the industry, that might be dangerous. If you just look back over the chemical industry to 1985, for example, you wouldn't see all the rollercoasters of 1974 to 1984. It's a bit dangerous if memories are too short. Some of the investment decisions will be cooled off, we think, and that is not a bad thing."

Executives throughout the chemical industry agree, because of the spectre of overcapacity. Too many went through the early part of the decade—with wildly excessive capacity, massive layoffs of employees, and restructurings—for them not to worry about the same thing happening once again. It took too many years for capacity utilization rates to move from 70 or 80% to the magical 90% or above, where a company really begins to make money on petrochemicals, for there not to be a lot of scars.

And, indeed, it has seemed during 1989 that chemical companies were embarking on a new round of building that would rapidly lower capacity utilization throughout the industry. Polypropylene producers, it can be argued, have already done that, so that as they move into 1990, they will be facing significant overcapacity. For other products, too, that prospect is all too real.

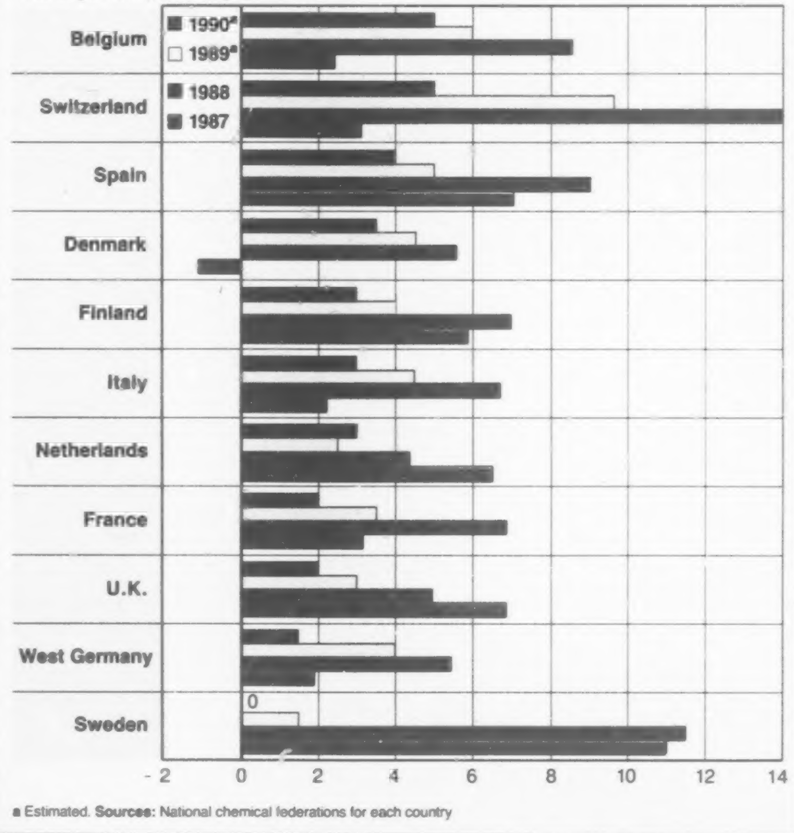
To some extent, companies are understandably matching their capital investment cycle to their business cycle. As David Culpin, a director of the U.K.'s Chemical Industries Association, points out, companies commit money to capital spending when they are making the money to commit.

Pierre-Yves Masson, president of Shell Chemical International Trading, adds that when companies have the money to spend, they must work to update their process technology and plant. They need the best technology available to maximize profit margins during good times and to be cost competitive when business turns down.

On the other hand, other executives in the industry argue, companies can't ignore conditions throughout the industry in their zeal to build new and better plants. One

Growth slows for chemical output in West Europe

% change from previous year



a Estimated. **Sources:** National chemical federations for each country potential saving for the industry is the willingness to shut down old capacity when a new plant is built. There is some indication that the industry is increasingly ready to do that.

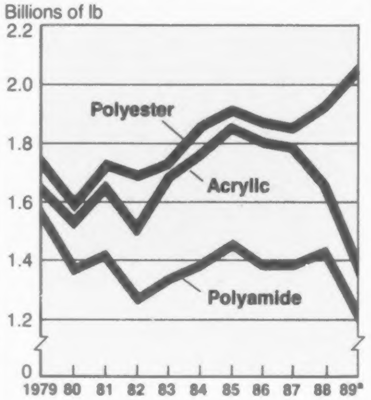
A case in point is the new polypropylene plant built by Appryl, a joint venture between Atochem of France and BP Chemicals, which built a new polypropylene plant with the intent of closing down the old one it replaced. Demand in the polypropylene market in Western Europe has been so good that it ran both, until the market finally began to cool down toward the end of this year; it is now closing the old plant, as originally planned.

Other sectors of the industry have also trimmed down radically. For example, during this past year, both ICI and West Germany's BASF have closed down fertilizer production or announced plans to do so. And West Germany's Hoechst has withdrawn from the fertilizer business entirely.

Still more trimming of capacity needs to be done in other sectors, many marketers agree. For example, Sir Christopher Hogg, chairman of Courtaulds, one of the major Western European producers of acrylic fibers, says acrylics won't move into solid profitability until more capacity throughout the industry is closed down. He was heartened by reports, earlier in 1989, that the two Italian fiber producers Snia-BPD (owned by Fiat Group) and Enimont were discussing links that might lead to the closing of some capacity. Since those early discussions, however, nothing has happened, and the acrylic fiber business is still suffering from both overcapacity and sagging consumer demand.

Disappointment that sectors of the fiber industry feel about the lack of any merger between Snia and Enimont has to be tempered by the fact that Enimont itself has come into being. The long-awaited merger of EniChem, the chemicals arm of the state-owned oil company ENI, with most of the chemical operations of privately held Montedison to create Enimont went into effect last January. And although there are still problems in meshing the two chemical businesses, because of a tortuous chain of Italian political and fiscal circumstances, Enimont now is a marketing and production force in Western Europe.

As polyester fiber output hits new high, others slump



ª Estimates. **Source:** CIRFS (International Rayon & Synthetic Fibers Committee)

And in France, the chemical industry has been waiting since March for a major study by the Ministry of Industry about the industry's restructuring. This will be the second major restructuring of the decade, as most of the industry's major portions were nationalized in the early 1980s. Still not officially released, the study is predicted to call for the dismemberment of one company, Orkem (formerly CdF Chimie), with its assets dealt to the remaining big companies, Atochem (the chemicals arm of oil company Elf Aquitaine, which is 45% owned by the government), state-owned Rhône-Poulenc, and an enhanced chemicals group at the other state-owned oil company, Total.

The goal of the French restructuring is to improve responsiveness to the marketplace by getting closer to the customer. Consumer demand, of course, is the final arbiter, and the closer to the final customer, the more a chemical supplier must keep an eye on the general economy. For example, PPG's Boswell notes that his company in Western Europe is particularly linked with the automotive and construction industries. When those businesses are good, PPG's is, as well.

For example, he points out that business in the automotive industry has been much stronger than economists had predicted. Auto production in 1988 hit 14 million, up 5% over 1987, and few people expected much further growth this year. However, output is up at least 2%, Boswell says. It won't be until 1990, he adds, that the automotive business will flatten out, or possibly even drop off 2%.

The closer one gets to the final consumer, also, the more environmentally responsive a company has had to be. This year, however, has been a year in which the environment—particularly waste disposal, including plastics waste disposal—has become a hot topic in Western Europe. Public concern and pressures have hit home to the point that industry has finally begun taking serious action to tackle new methods of waste disposal, for example, or develop alternatives to chlorofluorocarbons.

Biodegradability is one way to alleviate part of this problem. By early next year, for example, Montedison, working with its agroindustrial parent Ferruzzi, plans to introduce a new line of biodegradable plastics that will have a high starch content. "We must pay attention to development of nonpollution processes and production and to product quality," emphasizes a Montedison executive.

With momentum slowing but not stopping, it seems likely that there will be few dramatic changes ahead for the industry in Western Europe in 1990. Instead, it will be a year of continuation—of industry restructuring, rationalization, and diversification programs, in particular.

With the prospect of overcapacity looming, if not within Western Europe then elsewhere, marketers aware of restructuring needs will be increasingly willing to consider

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options such as joint ventures or shared production sites as a means of meeting needs without swamping the marketplace. The Finaneste cracker in Antwerp, due to come on stream in 1990 as a joint venture between Belgium's Petrofina and Finland's Neste, is perhaps the first in what will be a round of such joint projects.

One controlling factor will be the merger policy currently being worked out by the European Commission, which would play a transnational European role equivalent to that of U.S. antitrust authorities. For various reasons, the policy has been stuck in Brussels, as the commission addresses reservations held by the different member countries. But it is expected to be passed soon in the coming year.

The commission also will be concentrating its drive towards agreement on a social charter, which, among other things would bring worker representation to corporate boards of directors. Such a notion is being fought adamantly by the British government, although worker representation has been standard fare in other Western European countries for years.

Points out Boswell of PPG, which has worker representation on the boards of its West German and Dutch subsidiaries, "most responsible managements, in making important business decisions, will have the welfare of employees as a major concern. Representation on the board brings it up to a more senior level." However, he adds, "dialogue just at the board level would be ineffective—the key is day-to-day dialogue, in a more open environment. That is healthy."

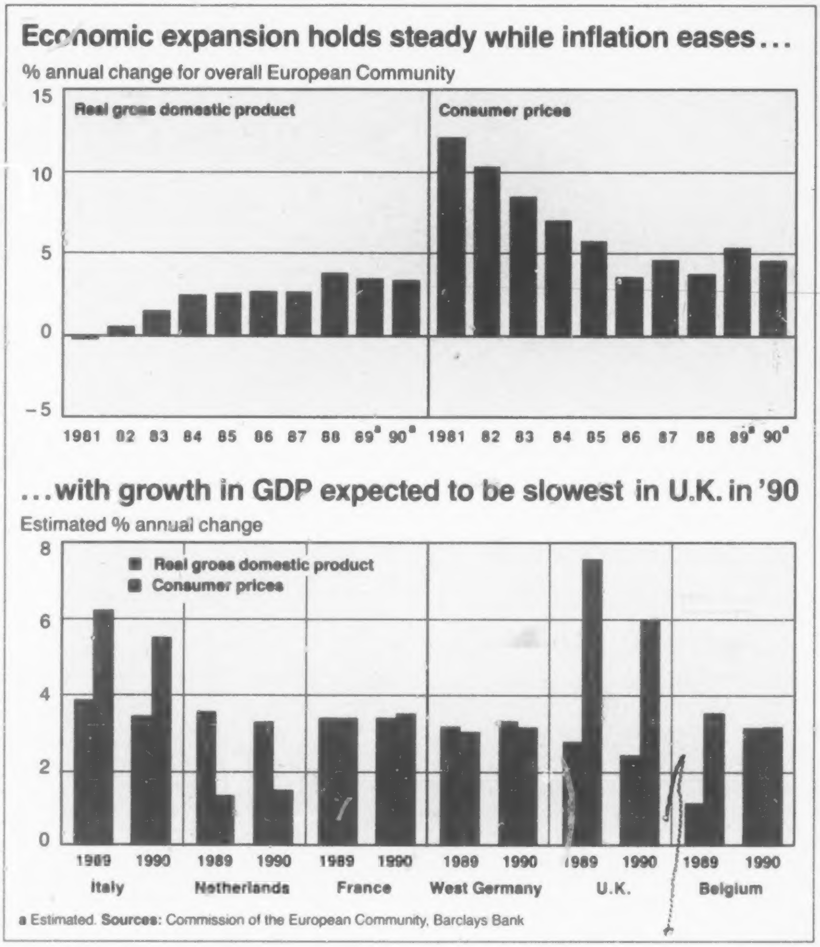
Despite the current continuing good profitability of petrochemicals, chemical companies continue their drive toward diversification, as a cushion against future downturns. As BP Chemicals' economists point out, "The current strong funds flow from petrochemicals provides the means to consider, as an option, further moves into specialties."

Investment will continue in capital assets or corporate acquisitions, virtually independently of whatever is happening to currency exchange rates. One Akzo executive explains, "The dollar does not influence our plans to make acquisitions in the U.S. (or elsewhere). Our strategy, and the opportunity to make an acquisition that fits into this strategy, are dominant." At Akzo, that strategy aims "at a well-balanced product mix. Petrochemicals in general may have been very profitable lately, but we think that in the long run, a well-balanced product mix is to be preferred."

That philosophy is echoed by Bayer of West Germany. A spokesman notes, "Acquisitions made by Bayer in the U.S. are part of long-term strategic planning, and are not affected by short-term fluctuations. One major factor in acquisitions, however, is the current high price of U.S. companies, due primarily to the takeover fever which has gripped the U.S."

In general, Bayer's acquisitions are strategic, to broaden its presence in the global market or gain market share in a product sector, as with its acquisition of the medical diagnostics company Cooper Technicon in 1989. Adds the company, "We prefer to opt for high, stable earning rates in the long term (with specialties) rather than very high earnings some years and lower earnings in others (in commodities)."

The prospects for 1990, therefore, seem to be more of the same, but at a slightly less brisk pace. On the assumption, though, that production of commodity chemicals trails slightly that of chemical products closer to the consumer, the industry may find some encouragement in the prediction of PPG Industries, with its auto and construction-sensitive businesses. "We see 1990 as a soft landing year," says Boswell, "maybe with a bit of a pickup for 1991. There is a potential falling off—a mild downturn, then business will come back. It's just part of the cycle." ☐



Economic expansion holds steady while inflation eases . . .

% annual change for overall European Community

. . . with growth in GDP expected to be slowest in U.K. in '90

Estimated % annual change

a Estimated. **Sources:** Commission of the European Community, Barclays Bank

Japan

Surge in chemical profits will ease as economy slows

Demand continues strong, but chemical producers find costs now rising faster than selling prices

Earl V. Anderson
C&EN Northeast News Bureau

Japanese chemical companies may soon have to tighten their belts. Increasingly, signs point to a slowdown in the high-flying Japanese economy, which is likely to result in slacker demand for chemical products and bring an end to the soaring profits that Japanese chemical companies have enjoyed for the past two years.

This does not mean that the Japanese chemical industry will have to suffer through hard times, as it did during the 1982 recession. It means only that the good times may not be quite so good as they have been for the past two years.

A recent survey conducted by the Japan Chemical Industry Association (JCIA) bears this out. According to JCIA, industry sales increased during the quarter ending last September (the second quarter of Japan's 1989 fiscal year, which ends in March 1990). But, for the second consecutive quarter, sales were not so high as estimated earlier.

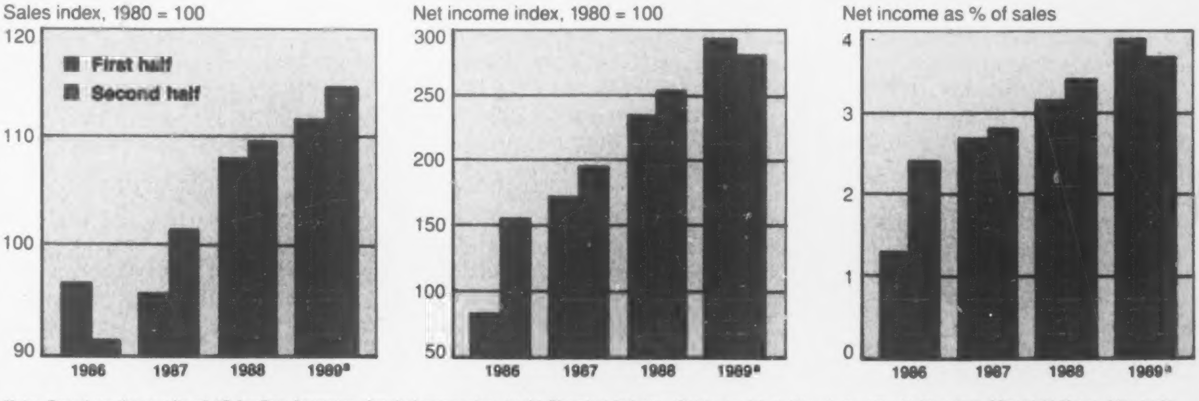
Many Japanese chemical executives who responded to the survey think that present business conditions, which they characterize as "favorable," will continue at least through the end of next March. However, an increasing number of them believe that conditions could take a turn for the worse by the end of this year.

In fact, compared with past JCIA surveys, fewer chemical company executives believe that present business conditions are favorable. An increasing number now complain that raw material and operating costs are rising faster than selling prices, dimming the short-term profit outlook. They label business conditions as "moderate" to "bad."

Those terms, of course, are highly subjective. But a more quantitative measure seems to confirm that Japanese chemical companies are facing, if not bad times, at least tougher times. This measure is the sales and earnings estimates of 12 leading Japanese chemical companies made by Toyo Keizai Inc., a leading Japanese financial publisher.

Its estimates indicate that sales of the 12 companies were up an average 3% in the first half of fiscal 1989 and likely will increase another 4% in the half that will end next March. However, net income of the

As sales edge higher for chemical producers . . . **. . . profits make another strong advance this year . . .** **. . . further widening the industry's profit margin**



Note: Based on the results of 12 leading Japanese chemical companies: Asahi Chemical Industry, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasai, Mitsubishi Petrochemicals, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these Japanese companies ends March 31 of the following year. a Estimated for second half. **Source:** Toyo Keizai, Shinposha companies, which advanced almost 26% in the first half, will be up only 13% in the second half.

That's hardly a doomsday outlook. But it does indicate that, in the Japanese chemical industry, profits will be harder to come by as the overall economy downshifts from rapid to a more moderate growth.

According to most Japanese economists, the country's economic growth rate is slowing down and will continue to slow down throughout 1990. Japan's fast-paced economic growth started in late 1986 when Yasuhiro Nakasone, then prime minister, launched a massive spending program on public works. Growth has been kept at a fast pace by strong housing construction, heavy capital investments, and soaring consumer spending.

Now housing starts are moderating. And according to Japan's Economic Planning Agency, the consumer buying binge, although still high, is starting to plateau.

Three other pillars that have helped to support Japan's economic growth over the past two years have been a stronger yen, low interest rates, and inexpensive oil. But the yen is weakening. It has gone from 123 yen per U.S. dollar at the beginning of the year to 143 yen per dollar at the end of last month. That 12% shift is significant, because it makes imported raw materials more expensive for Japanese companies.

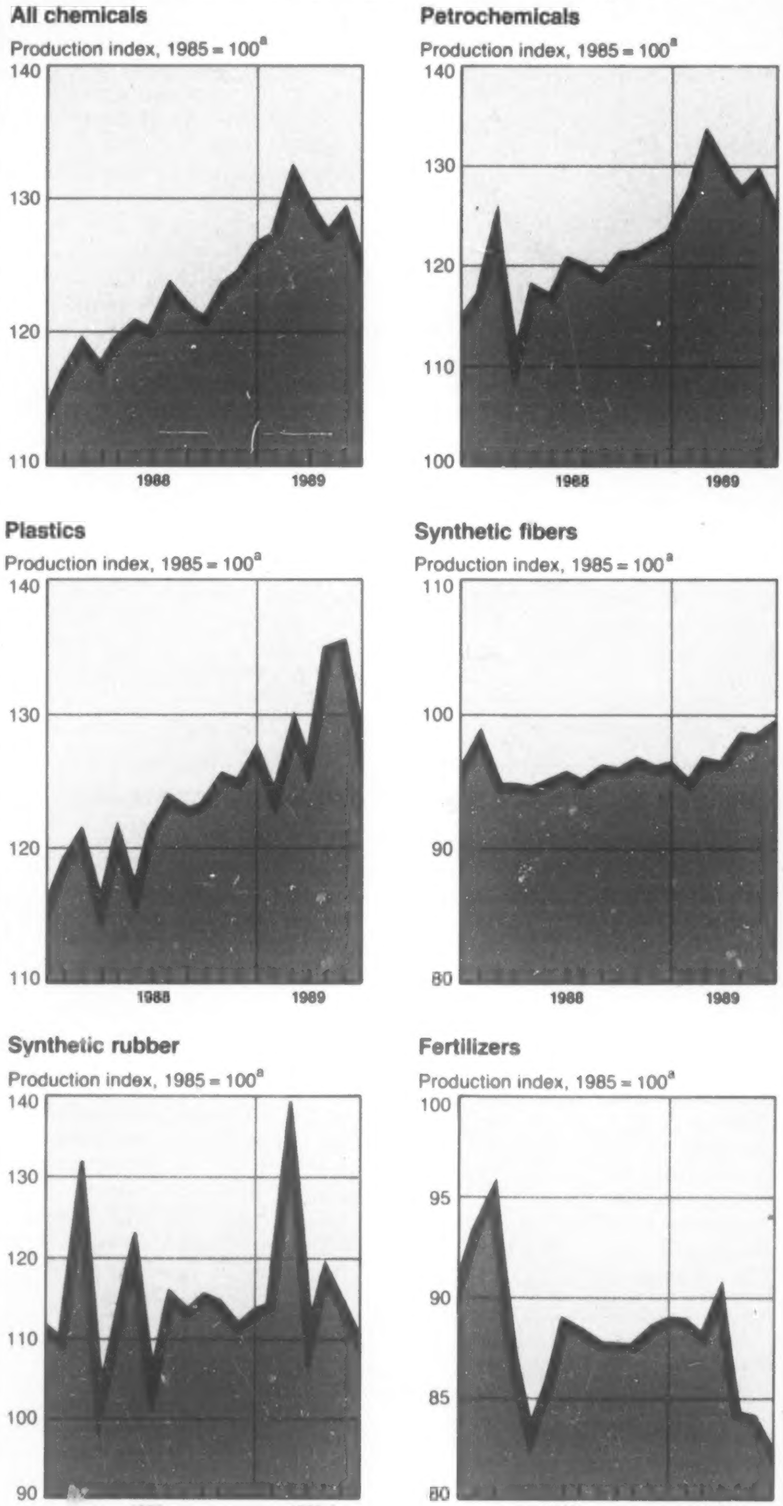
Meanwhile, oil prices, critical to a country that imports virtually all of its oil, have been going up. Prices for crude imported into Japan have risen about $5 per barrel this year and now stand at about $16 per bbl.

Interest rates, too, are going up. The Bank of Japan has raised the official discount rate 1.25 points to 3.75% this year. Although that is low compared with interest rates in the U.S., any hike tends to put a damper on economic growth.

The one part of the growth equation that probably will remain intact is capital spending. More than half of 50 Japanese companies surveyed on their fiscal 1990 plans say they expect to increase capital spending. Only five indicated that they would cut it.

The U.S., with whom Japan has had more than its share of trade

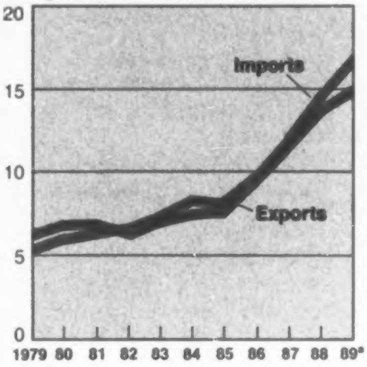
Japanese chemical output generally strong again in 1989



a Seasonally adjusted. **Source:** Ministry of International Trade & Industry

Spurt in imports worsens chemical trade balance

Foreign trade in chemicals, $ billions



a C&EN estimates.
Source: Ministry of International Trade & Industry

squabbles, has expressed concern about Japan's heavy capital expenditures. The U.S. is afraid that such outlays may lead to overcapacity, then overproduction, and, subsequently, to a new surge in Japanese exports.

Sensitive to foreign criticism of huge trade surpluses, the Ministry of International Trade & Industry (MITI) plans to launch a program next April to encourage imports of manufactured products. Among other things, it will offer tax incentives and low-cost loans to Japanese companies that import more foreign products.

Japanese business executives insist that most of their investments are aimed at meeting domestic demand, not at launching a new export offensive. This certainly seems to be the case for the chemical industry. Japan's chemical trade balance has been in the red every year since 1982. This year will be no exception.

In fact, the country's chemical trade deficit will just about double this year to $1.7 billion. That's because chemical exports are likely to increase only 7% to $15 billion, while chemical imports will jump almost 13% to $16.7 billion.

Because imported chemicals already represent a substantial part of domestic supply, some Japanese chemical companies are wary of MITI's plan to encourage additional imports. They argue that if competition from imports becomes too intense it could pressure Japanese chemical companies into beefing up their export business. That would only help to increase Japan's overall trade surplus, which is exactly what MITI doesn't want to happen.

Meanwhile, with the exception of fertilizer and synthetic rubber, Japan's chemical industry continues to chug along on the wings of the country's still-strong economy. The petrochemical segment has been particularly robust. Production of ethylene, the bellwether of the industry, probably will hit a record high, topping 5.5 million metric tons. Last year's output was 5.2 million metric tons.

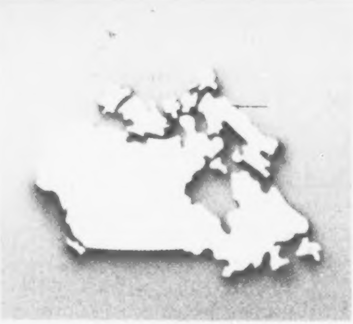
Japan's ethylene capacity is now about 6 million metric tons per year. Plans are in the works for six new ethylene plants, but chances are that not all of them will be built. MITI, taking a go-slow approach, is pressuring the industry to scale back its ethylene construction plans. It doesn't want to see a basic industry such as petrochemicals fall back into the overcapacity trap. □

Organics and plastics are outpacing inorganics this year

Thousands of metric tons unless otherwise indicated	1988	Seven months		% change
		1989	1988	
INORGANIC CHEMICALS				
Ammonia	1817	1065	1050	1%
Ammonium chloride	299	173	178	−4
Ammonium sulfate	1834	1006	1062	−5
Calcium carbide	342	220	224	−2
Calcium superphosphate	476	274	287	−5
Carbon black	720	448	417	7
Chlorine, liquid	979	603	576	5
Hydrochloric acid	565	325	328	−1
Nitrogen[a]	6940	4480	4005	12
Oxygen[a]	7707	4752	4450	7
Sodium carbonate	1083	651	630	3
Sodium hydroxide	3508	2097	2017	4
Sodium silicate	721	421	400	5
Sulfuric acid	6766	3990	3915	2
Titanium dioxide	258	161	149	8
ORGANIC CHEMICALS				
Acetaldehyde	333	203	194	5
Acetic acid	402	231	225	3
Acetone	289	190	172	11
Acrylonitrile	600	352	344	2
Benzene[b]	2374	1565	1364	15
Butadiene	780	473	441	7
Butanol	276	164	154	7
Caprolactam	493	276	291	−5
Cyclohexane	561	385	342	13
Dioctyl phthalate	273	169	152	11
Ethylene	5162	3177	2861	11
Ethylene dichloride	2301	1405	1289	9
Ethylene glycol	349	282	213	32
Ethylene oxide	510	370	299	24
Methanol	141	47	117	−60
Octanol	273	155	147	5
Phenol	358	239	216	11
Phthalic anhydride[b]	171	92	98	−6
Propylene	3682	2294	2098	9
Propylene glycol	265	161	151	6
Styrene	1757	1147	969	18
Terephthalic acid	1150	702	678	4
Toluene	1019	602	607	−1
Toluene diisocyanate	96	56	50	12
Urea	790	458	469	−2
Xylene	1988	1408	1131	25
PLASTICS				
Phenolic resins	356	219	206	6
Polyethylene	2380	1513	1324	14
Polypropylene	1559	966	883	9
Polystyrene	1891	1140	1057	8
Polyvinyl chloride	1838	1125	1034	9
SYNTHETIC RUBBER	1299	789	758	4

a Millions of cubic meters. b Petroleum-based product only. **Source:** Ministry of International Trade & Industry

Canada



Markets for chemicals soften at home and abroad

Earnings are being undercut by lower prices while falling exports put trade balance into red

Earl V. Anderson
C&EN Northeast News Bureau

The Canadian chemical industry is starting to feel the impact of softer markets and a stronger Canadian dollar, which is hurting chemical exports.

For some major chemicals, production is declining. For others, growth in output is slowing noticeably. Sales and earnings of most Canadian chemical companies are weakening. Prices are lower. And Canada's chemical trade balance has turned around completely—from a $400 million surplus (in U.S. dollars; $1.00 = $1.19 Canadian dollars on average for the first nine months of 1989) in 1988 to a $757 million deficit this year.

What's more, little relief is in sight for the next two or three quarters. Demand is expected to remain sluggish for at least that long. And, if that turns out to be the case, Canadian chemical companies will be hard-pressed to improve their faltering earnings.

Earnings are, indeed, faltering. At Celanese Canada, profits are down 0.3% through the first nine months, despite a healthy 14% gain in the first quarter. Du Pont Canada's earnings, which fell in the first and second quarters from a year earlier, dropped a hefty 30% in the third quarter and are off 17% for the year through September.

At Union Carbide Canada, the story is similar. After chalking up a whopping 80% increase during the first quarter from 1988's like period, profits plummeted 64% during the third quarter. For the first nine months, Carbide Canada's earnings are off 12%.

Carbide Canada's chairman W. Norman Kissick blames sharply lower ethylene and polyethylene prices for his company's earnings decline. Du Pont Canada also points the finger at lower polyethylene prices, as well as lower sales volumes for polyethylene and carpet fibers. At Celanese Canada, the culprit is methanol. Lower methanol prices, which started showing up in the second quarter, contributed strongly to the company's lower net income.

The story repeats itself throughout the Canadian chemical industry. Lower prices for styrene and its polymers worldwide have hit Shell Çanada Chemical's earnings. And Sherritt Gordon's fertilizer division suffered a loss in the third quarter, primarily because of sharply lower urea prices in export markets.

Nova Corp., which became a petrochemical kingpin in Canada since it acquired Polysar Energy & Chemical last year, is particularly hard hit. The big reason: Basic petrochemicals now account for about two thirds of Nova's earnings, and since early in the year prices for its petrochemical products have gone down an average 30 to 35%. Nova's third-quarter income from petrochemical operations was only $41 million this year, sharply lower than last year's $203 million.

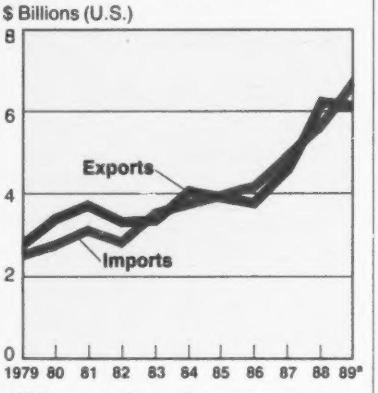
Little surprise, then, that Nova has decided to delay construction of a third ethylene plant at Joffre, Alberta, and has put on hold plans to build a new linear low-density polyethylene plant there. Nova, which already operates two ethylene units at Joffre with a combined capacity of 1.36 million metric tons, originally planned to bring its third

Signs of weakness show up in chemical production

	Production					% change
Thousands of metric tons	1989[a]	1988	1987	1986	1985	1988-89
Ammonia	4300	4010	3512	3540	3620	7
Ammonium nitrate	1085	981	844	948	1054	11
Ammonium phosphate	1010	986	941	1149	1301	2
Benzene	690	695	720	635	688	1
Chlorine	1615	1664	1635	1536	1424	−3
Ethylene	2400	2346	2140	1909	1744	2
Hydrochloric acid, 100%	180	180	164	153	158	0
Phosphoric acid, 100%	500	475	464	547	627	5
Polyethylene, high density	305	311	269	242	229	−2
Polyethylene, low density	990	1105	1021	887	733	−10
Propylene	760	669	628	628	648	14
Sodium chlorate	585	503	432	373	336	16
Sodium hydroxide	1595	1720	1770	1696	1589	−7
Sulfuric acid	3680	3805	3437	3536	3890	−3
Urea	2500	2372	2142	2330	2033	5

a C&EN estimates. **Source:** Statistics Canada

Chemical trade balance slips into red this year



ª C&EN estimates. **Source:** Statistics Canada

unit on stream in the fall of 1992 with a capacity of 680,000 metric tons. That planned capacity was later shaved to 540,000 metric tons.

Meanwhile, in British Columbia, Westcoast Energy and its partners also have deferred work on a petrochemical project that they planned to build at Taylor. The project would have included a 340,000-metric-ton ethylene plant, as well as plants to produce polyethylene and ethylene glycol.

These two moves will help keep ethylene supplies from far outdistancing demand in the early 1990s because Canadian ethylene capacity is slated to increase even without the Nova and Westcoast plants. Dow Chemical Canada, for instance, is building a 500,000-metric-ton unit at Fort Saskatchewan, Alberta. Polysar is expanding ethylene capacity at Sarnia, Ontario, by 90,000 metric tons. In Quebec, Pétromont is adding 45,000 metric tons to its Varennes capacity and is even considering doubling capacity there.

Canadian ethylene producers have been operating their plants at or near capacity, at least through August, the latest month for which production statistics are available. Nevertheless, output by year's end should reach no more than 2.4 million metric tons, only 2% higher than last year.

Canadian ethylene output, however, could go higher as a result of the explosion at Phillips 66's high-density polyethylene (HDPE) plant in Pasadena, Tex. That accident wiped out an estimated 16 to 17% of U.S. HDPE capacity, and Canadian producers are logical contenders to make up some of the shortfall.

Through the first eight months of the year, Canadian HDPE production was running 2% behind last year's pace. At that rate, it would close the year at 305,000 metric tons. That figure is likely to rise only if Canadian HDPE producers are able to take up some of the slack in the U.S. market.

Meanwhile, output of low-density polyethylene (LDPE), including linear low-density material, is faring even worse. Output for the year will probably be down 10% to 990,000 metric tons.

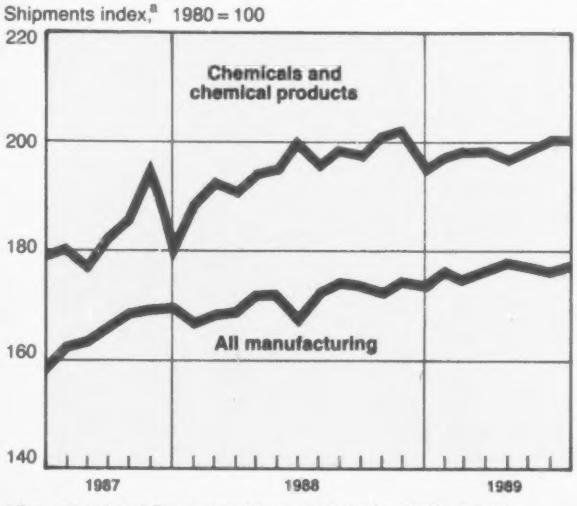
One reason for the decline in Canadian ethylene derivatives production no doubt is the softer demand overseas. For most petrochemicals, Canadian capacity far exceeds domestic demand. As a result, producers depend heavily upon strong export markets.

But those strong export markets aren't there this year. Exports of synthetic rubber and plastics are running 10% lower than last year. Meanwhile, inorganic chemical exports are down 12 to 18%, and fertilizer exports are off 8%.

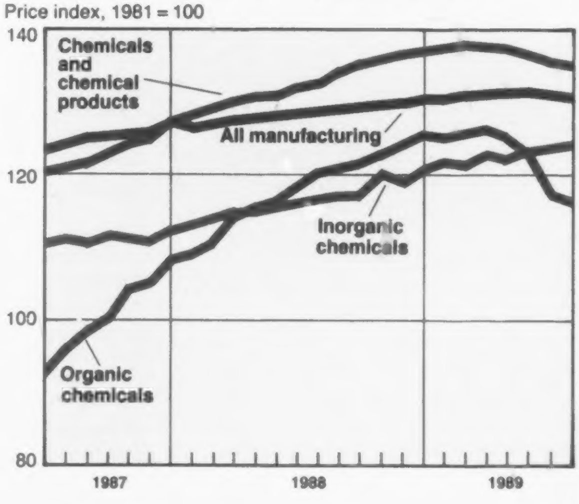
The bottom line is that Canadian chemical exports are likely to decline 6% this year to $6.1 billion, while imports will increase 13% to $6.8 billion. Despite the many fingers that will be pointed at the Canada-U.S. trade pact, the real reason for the disparity is that worldwide demand for Canadian chemicals has lost some of its strength.

A major factor in this export weakness is the strong Canadian dollar, which makes Canadian products more expensive in world markets. And as long as the Bank of Canada keeps interest rates high to combat inflation, the Canadian dollar will remain strong and Canadian chemical companies will find competing in the world marketplace more difficult. □

Growth of chemical shipments slows...



...as organic chemical prices soften



ª Seasonally adjusted. **Source:** Index based on Statistics Canada shipments data

U.S.S.R./Eastern Europe

Political changes may open East bloc chemical sector

Soviet, East European chemical industries need massive efforts to overcome deeply rooted stagnation

Richard J. Seltzer, C&EN Washington

For years, the economies of the Soviet Union and its East European allies—Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania—have displayed increasing stagnation, plagued by structural problems deeply rooted in their centrally planned systems. Indeed, the resulting malaise contributed mightily to the political upheavals and wave of democratization that have swept all East Europe but Romania in recent months.

Sooner or later, the revolutionary euphoria will fade. But the East bloc nations still will face years of massive efforts to carry out fundamental changes, introduce market forces, build infrastructures, and transform systems and institutions. Rapid improvement in economic and industrial performance is thus unlikely. However, these efforts may well open up wide opportunities and challenges for Western industry through investments, joint ventures, and other links—with chemical industry probably playing a key role.

Gross industrial output for the region grew just over 2% through September this year, compared with 4% through September last year, according to a report by the United Nations Economic Commission for Europe. This weakening performance reflects a variety of supply constraints and transport bottlenecks, UNECE notes.

For one thing, strikes, interethnic conflicts, and a drop in labor and management discipline in the Soviet Union have caused raw material, equipment, and energy shortages. Exacerbated by Soviet transport problems, these shortages appear to be spilling over into neighboring economies through reduced exports. Hungary, the U.S.S.R., and Poland are trying to fight inflation with austerity measures that likely will further slow industrial growth.

Indeed, Soviet president Mikhail S. Gorbachev's perestroika (restructuring) program, which ignited the blaze that has swept East Europe, "has yet to yield positive results," notes a recent report by WEFA Group (formerly Wharton Econometric Forecasting Associates). In fact, adds a report from PlanEcon

Soviet, East European output slows for some chemicals

Thousands of metric tons, 1988	U.S.S.R.	Bulgaria	Czechoslovakia	East Germany	Hungary	Poland
Mineral fertilizers[a]	37,100	1134	1025	5192	900	2718
Change from 1987	2.1%	21.5%	4.2%	1.4%	0.8%	3.7%
Nitrogen (N)	15,800	956	596	1382	na	1622
Change from 1987	0.4%	18.8%	0%	4.9%	na	5.1%
Phosphate (P_2O_5)	10,000[b]	178	313[b]	300[b]	na	962
Change from 1987	3.2%	39.1%	13.0%	3.0%	na	2.1%
Potassium (K_2O)	11,300[c]	0	116[c]	3510	na	134[c]
Change from 1987	3.8%	—	4.6%	0%	na	−2.2%
Sulfuric acid	29,400	780	1249	799	512	3154
Change from 1987	3.0%	13.2%	−1.2%	−7.8%	−10.6%	0.2%
Ammonia[d]	20,330	1336	774	1160	na	1923
Change from 1987	2.0%	24.9%	−0.8%	−1.7%	na	7.4%
Plastics	5,672[e]	344	1180	1149	600	723
Change from 1987	3.4%	6.8%	2.4%	8.3%	11.3%	12.8%
Sodium hydroxide	3,324	129	337	627	202[f]	444
Change from 1987	1.1%	24.0%	−2.0%	8.6%	0.3%	5.2%
Synthetic rubber	2,485	24	77	104	—	127
Change from 1987	5.0%	0%	1.3%	5.1%	—	8.5%

Note: Romania is not included because data are unavailable. a Nutrient content basis. b Includes ground phosphate for direct application and phosphate animal feeds. c Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. d Nitrogen content basis. e Includes resins for man-made fibers. f Includes regenerated NaOH. na = not available. **Sources:** PlanEcon Inc., Central Intelligence Agency, state central statistical bureaus

Inc., a Washington, D.C.-based firm specializing in research on the Soviet and East European economies, perestroika, "while politically and socially exciting, is proving disastrous for the Soviet economy."

Soviet industry stagnated in 1988, with major sectors showing no growth in real terms. Industrial production rose just 2.4% by Central Intelligence Agency calculations (correcting the Soviet figure of 3.9% to eliminate upward bias due to double-counting and disguised inflation). This fell below the target of 4.4%. Chemical growth in 1988 was just 1.8% by CIA figures.

This year, through September, the Soviet figure for industrial growth is only 2.2%, compared with a target of 3.1%. All sectors fell short of their targets, with the "chemical and timber complex" up just 1.9% by Soviet figures. The third quarter was even worse than the first six months, notes Zuzana Princova, director of WEFA's centrally planned economies unit in London. The complex's output in the third quarter fell 9% below that in 1988.

The critical situation forced the Soviets to prepare a plan for 1990 that proposes a fundamental shift of resources, which would cut investment in heavy industry and construction 30% and redirect part to making consumer goods and part to reducing the large budget deficit.

In East Germany, one of East Europe's top chemical producers, economic growth also ground nearly to a halt in 1988, notes PlanEcon. Like East Germany's industry in general, the growth rate for the chemical sector, including rubber and plastics, has declined continually since the early 1970s. The sector is now growing at less than half the annual average of 8% it racked up from 1971 through 1975. Production of sulfuric acid dropped 8% in 1988, for example, while output of hydrochloric acid was essentially unchanged and ammonia was down 2%.

The chemical industry has suffered from economic policies that have inhibited East German industry overall, notes PlanEcon. These policies included pushing exports (especially hard-currency exports) at any cost while neglecting not only investment and modernization but also the general infrastructure needed by industry to maintain high growth rates. Also hindering industrial operations have been expensive social policies—such as overspending on housing construction and price subsidies—and excessive dependence on dwindling domestic sources of energy.

East Europe's other top chemical producer is Czechoslovakia. Like East Germany, Czechoslovakia's overall industrial growth, as well as growth of its chemical industry, has slowed in the 1980s to less than half the rates in the early 1970s (an average 7% a year for 1971 through 1975 for all industry and 10% a year for chemicals and rubber). Industrial output overall rose just 2% in 1988 and only 1% in the first six months of 1989. Chemical output also grew just 2% in 1988. Production of a number of key chemicals dropped in 1988, including nitric acid (down 3%), sodium hydroxide (down 2%), and sulfuric acid and ammonia (both down about 1%).

Czech industry has not suffered from the type of macroeconomic adjustment forced in Hungary, Poland, and Romania by mounting foreign debt and economic policy flaws, points out PlanEcon. But, the firm says, "all of Czechoslovak industry, including the chemicals sector, is becoming increasingly obsolete and outmoded and is experiencing problems with improving both the quality and quantity of output."

East German chemical growth half that of early 1970s

Chemical production, % annual change	1971–75	1976–80	1981–85	1986	1987	1988
All industry	6.3%	4.9%	4.1%	3.8%	3.2%	3.3%
All chemical industry[a]	8.3	4.8	3.8	2.2	2.6	3.5
Oil, gas, and coal-derived chemicals	7.7	4.4	3.9	1.4	3.6	1.7
Plastics	11.7	5.3	4.3	−1.8	−1.5	10.4
Man-made fibers	13.2	4.3	4.2	0.4	2.8	5.1

[a] Includes rubber industry. **Source:** PlanEcon Inc.

East German and Czech chemical industries would be the most attractive in Eastern Europe to Western investors, notes Jay K. Mitchell, manager of Soviet and East European chemical services at PlanEcon. West German chemical firms have a great advantage, he points out. Economic and environmental cooperation between the two Germanies was already increasing markedly, even before the recent political upheaval. West Germany already takes about 60% of East Germany's trade with the West.

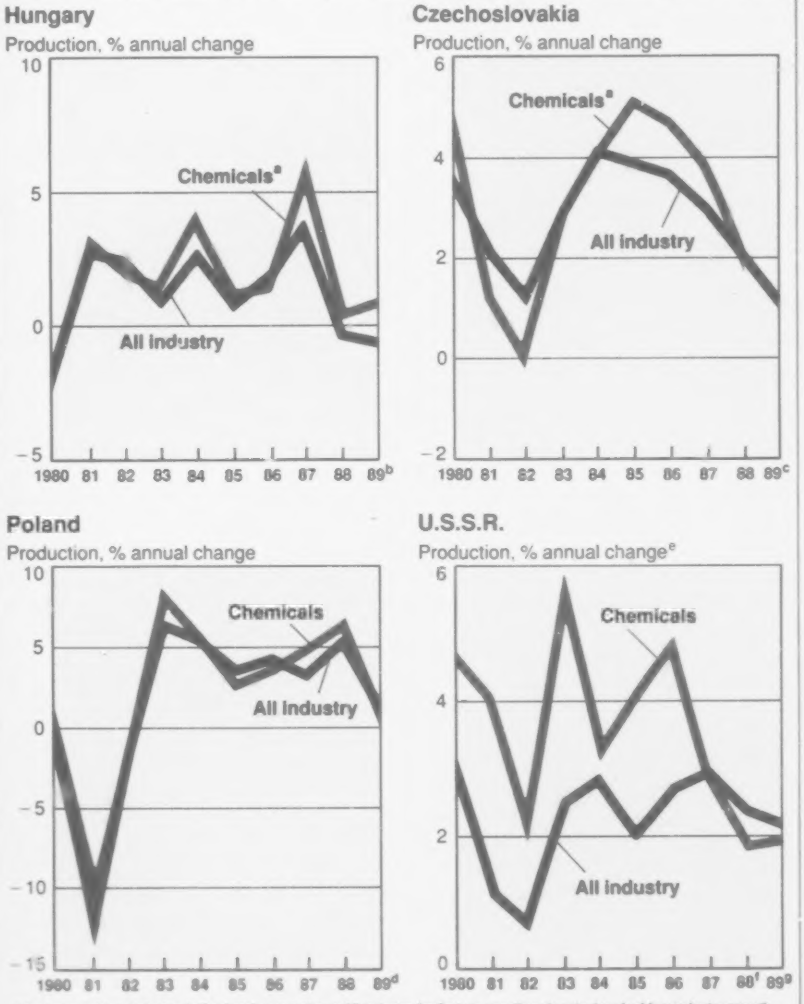
Of the East Bloc nations, Hungary is so far probably farthest along the path to comprehensive reform. However, says PlanEcon, worsening inflation and a growing foreign debt crisis, "along with government inability (until recently) to accept the necessity of radical, rather than hesitant, economic reforms" have resulted in generally poor Hungarian industrial performance since 1980.

Last year, for instance, overall industrial production dropped 0.4%, and through July of this year it dropped another 0.4%. Chemical output rose just 0.3% in 1988 and 0.8% through May of this year. Production dropped for several key chemicals in 1988, including sulfuric acid (down 11%) and pesticides (down 7%), and stayed nearly unchanged for others, such as caustic soda and mineral fertilizers.

However, political reforms, an aggressive privatization program, a stock market, and joint ventures have given new impetus to Hungary's modernization drive. For example, Hungary is offering 53 companies for foreign investment, including four chemical firms: Borsod Chemical Combine, Chinoin Pharmaceutical & Chemical Works, Pet Nitrogen Works, and Taurus Hungarian Rubber Works. General Electric last month spent $150 million for a controlling interest in Tungsram, a Hungarian light bulb maker.

Poland's economic situation has deteriorated this year, following significant growth last year (industrial production was up 5% and chemical output up 6%). Inflation is accelerating (exceeding 200%), production is lagging, labor discipline is

East Europe's industrial production generally falling in 1989



Hungary

Czechoslovakia

Poland

U.S.S.R.

a Includes rubber industry. **b** For first five months. **c** All industry for first six months; chemical and rubber industry growth in 1989 is not available. **d** For first six months. **e** All Soviet Union figures except for 1989 are based on Central Intelligence Agency estimates, which are lower than official statistics. **f** Preliminary. **g** For first nine months; official Soviet figure for 1989 is for "chemical and timber complex," rather than chemical industry. **Sources:** PlanEcon Inc., Central Intelligence Agency, United Nations Economic Commission for Europe, state central statistics bureaus

declining, and hard currency exports are falling short of targets. Industry output overall rose just 0.2% through July, while chemical production was up only 0.4% through June. July was disastrous, with industrial output down 6% versus July 1988 and chemical production down 10%.

The radical political changes Poland has undergone this year "have created unique opportunities" for solving its decade-long economic crisis, PlanEcon notes. But the changes "also have generated expectations which may prove hard to fulfill." Western aid, including that recently approved by the U.S. Congress, is "still rather meager compared to what is needed," and Poland has not yet undertaken the economic reforms and austerity policies it needs. All in all, PlanEcon is more pessimistic regarding Poland's chances for radical economic reform than those of Hungary.

Bulgaria is a relatively minor chemical producer, and PlanEcon projects only limited gains during the next few years. This is partly a reflection of its size (less than 9 million population) and partly because its chemical industry is still in early stages of development.

For example, Bulgaria produces relatively low amounts of products as sophisticated as plastics (344,000 metric tons in 1988) and man-made fibers (93,500 metric tons in 1987). Production of many chemicals, including plastics and fibers, actually has declined since the mid-1980s, despite swiftly rising imports of raw materials and intermediates from the West since 1985. And destruction of the Devnia polyvinyl chloride plant in late 1986 all but wiped out production of that plastic, with replacement not due for several years.

Bulgaria's industrial output rose 5% in 1988, as did its chemical output. Growth slowed to 3.5% and 3.3%, respectively, through September of this year.

Meanwhile, defying the waves of reform, Romania continues to go its increasingly isolated way under what PlanEcon calls "the mad schemes" of its authoritarian leader, Nicolae Ceausescu. Romania releases few detailed or reliable statistics, but what is known "clearly indicates the decline of the chemical industry," with output falling since 1985 for almost all products reported, PlanEcon says.

For example, in 1988 mineral fertilizer output was down 5%, plastics down 2%, sulfuric acid down 3%, and man-made fibers down 4%. Other chemicals probably have fared even worse, PlanEcon notes. Moreover, Romania has far fewer chemical facilities being supplied by Western firms than has any other East bloc nation, so it is likely falling increasingly behind not only world standards but even East European ones.

In March, the regime finally reached its goal of liquidating Romania's hard-currency debt—by slashing imports while boosting hard-currency exports. But deprived of domestic investment and foreign capital, the economy and industry suffered greatly. For instance, there has been little construction of new chemical plants or expansion of existing ones in recent years. Now that the foreign debt has officially been eliminated, Romania faces massive rebuilding to restore chemical capacity losses and overcome technological backwardness—if it gets desperately needed modernization funds from the "often irrational" Ceausescu, PlanEcon notes. □

China puts reforms on hold as economic problems mount

Political crackdown and ongoing austerity program shape outlook for chemical and other industries

Richard J. Seltzer
C&EN Washington

China's economic and industrial environment is currently being shaped primarily by two forces: the political crackdown that began in Beijing's Tiananmen Square six months ago and the nation's austerity program.

The crackdown was a watershed event. Until June 4, U.S. and other foreign investment in joint ventures had been accelerating, including chemically related projects. In 1988, the number of new U.S. investment contracts doubled to close to 600 with a commitment value of almost $3.5 billion. The 1988 total for all foreigner investors was almost $5 billion, with projections of more than $8 billion in 1989. Foreign executives saw a reformed investment regime, improved overall environment, and attitudes changing for the better among Chinese officials, notes Roger W. Sullivan, president of the U.S.-China Business Council.

Then came the crackdown, raising questions in foreign minds about China's stability and its commitment to a continuing process of liberalization, reform, and opening up to the world. Those who had projects in China have kept them going, but many considering investments have put them on hold.

U.S. experts differ on whether reform is essentially over. Some experts, such as Sullivan, depict Marxist-Leninist hardliners as "moving with remarkable speed and self-confidence to establish their dominance." Ironically at a time when East Europe is opening up, such leaders are taking their nation sharply backward, Sullivan believes, away from market forces and integration into the world economy and back toward Marxist central planning and greater political, ideological, and social control. Other specialists, such as Nicholas Lardy of the University of Washington, think reforms will continue and that the climate for foreign investment will improve after a period of consolidation.

In any case, a second major force acting on China's economy and industry is an austerity program imposed by its leaders. This program attempts to cool down soaring inflation, cut overly rapid industrial growth, and check increasing corruption and a deteriorating trade balance. The program has put economic reforms on hold for about a year already, although Chinese leaders have reiterated their commitment to reform. However, observers suggest that under the guise of austerity, hardliners may try to chip away at market-oriented reforms.

In 1988, industrial output surged 21% and gross national product rose 11%. This intensified China's chronic energy and raw materials shortages and transportation bottlenecks, and pushed inflation to its highest level in nearly 40 years—19% for the nation overall and almost 30% in the cities. Chemical production in 1988 soared for a number of key chemicals. Ethylene production was up 47%, insecticides 28%, pharmaceuticals 26%, and sulfuric acid 14%

As a result of the austerity program, inflation has indeed eased, but so has industrial production. Thus, industrial output grew 11% through July of this year, just half as much as in all 1988, and is continuing to weaken in the second half. One analyst predicts just 5% industrial growth for all 1989.

Output of ethylene was up 16% through July, insecticides 13%, and both pharmaceuticals and sulfuric acid 2%. However, the hardliners view inflation as the root cause behind popular dissatisfaction. They are ready to tolerate losses in economic activity and further unpopularity in hopes of achieving a more stable long-term price environment.

China's trade deficit also widened sharply last year, as it sought to import many industrial and agricultural products it couldn't supply domestically. For example, it sharply increased imports of fertilizer in the second half of 1988. U.S fertilizer exports to China last year leaped 40% from 1987, to $379 million. China also imported $596 million worth of plastics and resins from the U.S. (up 134%) and $257 million worth of organic chemicals (up 71%). □

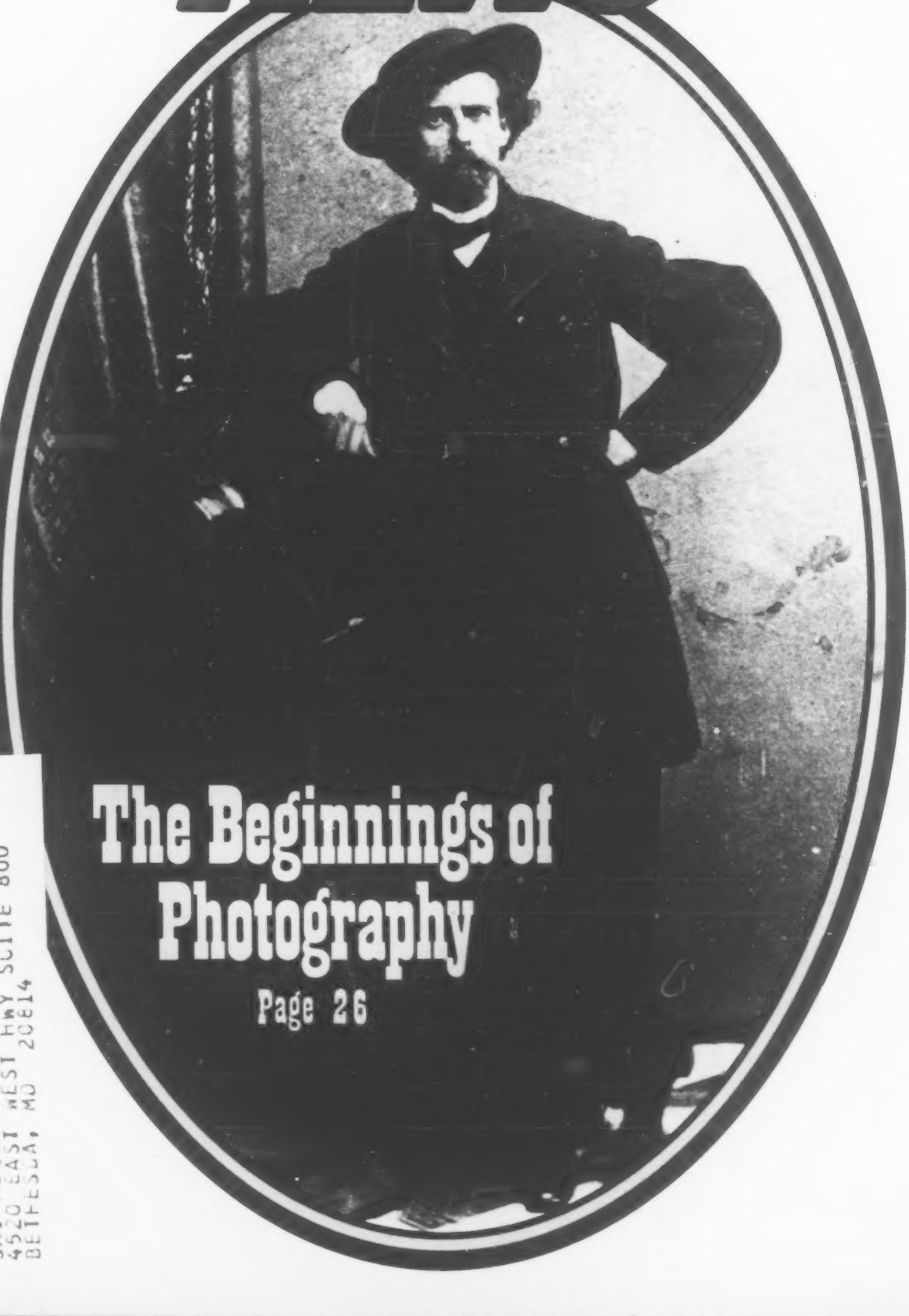
China's output of plastics, fibers up sharply in 1989

housands of etric tons	1989[a]	1988	% change 1988–89[a]
ynthetic ammonia	11,834	19,725	1.3%
ertilizer[b]	10,601	17,675	0
ulfuric acid	6,594	10,981	2.3
odium hydroxide	1,847	2,925	8.1
odium carbonate	1,597	2,593	2.2
lastics	1,192	1,552	31.3
an-made fibers	864	1,284	18.5
thylene	830	1,231	16.1
enzene	340	566	2.5
ynthetic rubber	173	251	13.2
esticides	140	202	12.7
harmaceuticals	114	194	2.4

For first seven months. b Nutrient content basis. **Sources:** State tatistical Bureau of the People's Republic of China, *China Economic News*

DECEMBER 18, 1989

CHEMICAL & ENGINEERING NEWS



The Beginnings of Photography

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- **Hawaii meeting of chemical societies from Pacific Basin nations is jointly sponsored by ACS, chemical societies of Japan and Canada.** **Page 5**
- **Phillips 66 plans to rapidly replace polyethylene capacity lost in Pasadena, Tex., explosion.** **Page 5**
- **Henry Helmuth Reichhold, founder of Reichhold Chemicals, dies.** **Page 5**
- **French government details long-awaited restructuring plan for its chemical industry.** **Page 6**
- **Frank E. Young, departing FDA chief, urges more resources and staff, better facilities for embattled agency.** **Page 6**

Cover: Early 1860s portrait of man (perhaps the photographer) with view camera. Photo courtesy of the Smithsonian Institution

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Government

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Greater use of renewable energy sources is the solution to the global warming problem and needs new commitment from the government, a recent study concludes. **Page 15**

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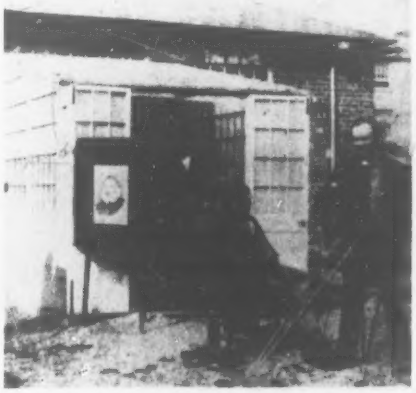
Chem Show '89 spotlighted chemical process industries hardware, software, services. **Page 17**

Polymerization using hydroboration process is achieved by chemists in Japan. **Page 20**



Special Report

Early efforts at photography led to a variety of images—daguerreotypes, calotypes, heliographs—using a wide range of chemical methods. **Page 26**

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LETTERS

Tritium in cold fusion

SIR: I have read with interest the recent reports (C&EN, Nov. 6, page 32) of the finding of tritium in the cold fusion electrolysis of deuterium oxide using palladium electrodes. However, the reports indicate the sporadic, unpredictable nature of the findings. This may be due to the fact that the tritium is already present in the deuterium oxide in variable amounts before the electrolysis begins. Heavy water is prepared by concentrating deuterium atoms from normal water, and it would be expected that tritium would be concentrated at least as much, if not considerably more. Even though tritium is present in much lower concentrations than deuterium, the enrichment would tend to make it be present in high enough concentrations to be found by normal analytical techniques.

None of the news reports indicate whether the starting heavy water has been analyzed for tritium and whether that which has been found is the differential between starting and final amounts. This is certainly a necessary step before any conclusive claim can be made for the production of tritium in the electrolysis process.

Amos J. Leffler
Professor of Chemistry
Villanova University

Nuclear power and the press

SIR: Ivan Legg's letter (C&EN, Oct. 30, page 2) reminded me of an exchange I had with ABC News some years ago.

In the mid-1970s we were attempting to obtain an operating license for the Barnwell nuclear plant, so were heavily involved in safety analysis. One evening on the wrapup portion of ABC News, Harry Reasoner called his science editor Jules Bergman to the fore and said, "Jules, we have been hearing a lot about the safety of nuclear power plants. How many people would be killed in an accident, as many as a million?" Jules replied, "Oh no, Harry, only 100,000."

I wrote a letter to Reasoner quoting the Rasmussen report (Wash-1400, "The Safety of Nuclear Power Plants") wherein estimates in worst-case analyses were much lower than the figures they gave on television. I received a reply from Reasoner saying he had turned my letter over to his science editor. I shortly received a reply from Bergman, in which he admitted to have spoken hastily, and that estimates of fatalities were much lower than 100,000.

Did ABC News or Reasoner ever admit to this gross overestimate on television? Of course not! Subsequent events at Three Mile Island and Chernobyl have shown that estimates in Wash-1400 were too high.

The executive summary of Wash-1400 compares risk estimates of nuclear power with events we are exposed to in our daily lives, such as riding in automobiles and airplanes, and events of nature. One of the standing jokes at that time went like this: "Did you hear that Norm Rasmussen's house was struck by a meteor? Fortunately, Norm was not hurt. He was in the hospital recovering from lightning burns."

Wesley Murbach
Tucson

Solution to teacher shortage

SIR: This immodest proposal, set in the context of recent experiences with chemical science education in the state of Texas, is in response to recent articles in the *Journal of Chemical Education* [Hilderbrand, D. C., Jensen, W. P., "A Partial Solution to the High School Chemistry Shortage," **66**, 427, (1989); Sedotti, M., Tanaka, J., "Rules Minimize Student Interest in Chemistry," **66**, 497, (1989)] and in C&EN's annual salary surveys and articles on the career distribution of certified graduates.

We in science education have been aware of the catastrophic shortage of chemistry and physics teachers in our secondary schools for a number of years. Principals and science coordinators have felt this "crunch" and have been pressing governing bodies, like the Texas Education Agency, to relieve the certification pressures. Large school systems in highly industrialized cities have instituted alternate certification programs so that scientists can make a transition from industrial positions to secondary teaching jobs without significant course requirements. Some states,

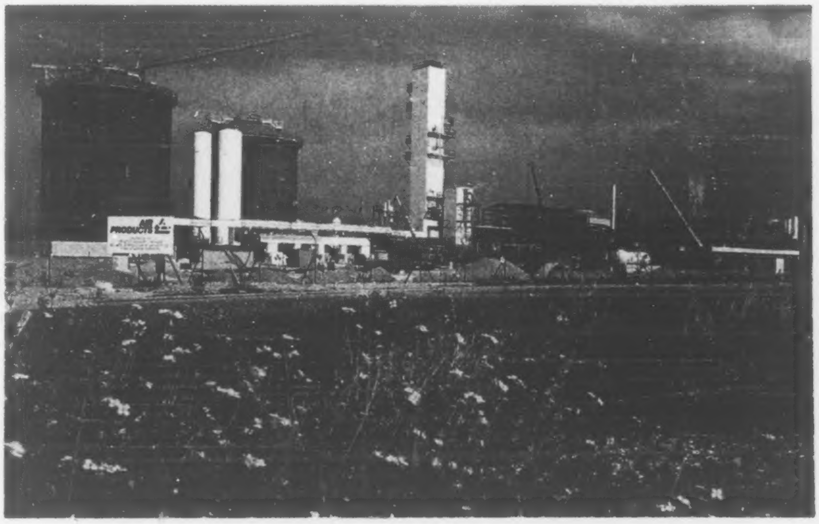
Correction

- Nov. 13, page 31: Panel discussion at Roosevelt University was moderated by David Slavsky, associate professor of natural sciences at Loyola University, Chicago, not Leonard Reiffel.

Chemical Capital Spending To Continue Steady Climb

Some forecasts seem overly ambitious, however, in view of weakening auto and housing sectors, lower plant capacity use, and slipping prices

Marc S. Reisch,
C&EN Northeast News Bureau



Air Products air separation plant under construction in France

Worldwide capital spending by U.S. chemical companies will increase modestly again in 1990, according to preliminary forecasts by leading chemical producers. However, only eight of the 12 major chemical producers that C&EN surveys every year at this time were able to forecast their 1990 expenditures. For those eight companies, 1990 capital spending will rise 12% from 1989 to a combined \$4.74 billion. That forecast follows a somewhat lower 1989 increase of 10% for reporting firms.

Predictions of an economic downturn have caught a number of companies unaware. At this time in 1988, a stronger than expected economy caught companies off guard as well, and so only nine of the 12 companies in the survey were able to come up with capital spending predictions. When the same 12 companies were queried in early December of 1987, 11 of them were confident enough to predict their capital spending for the following year.

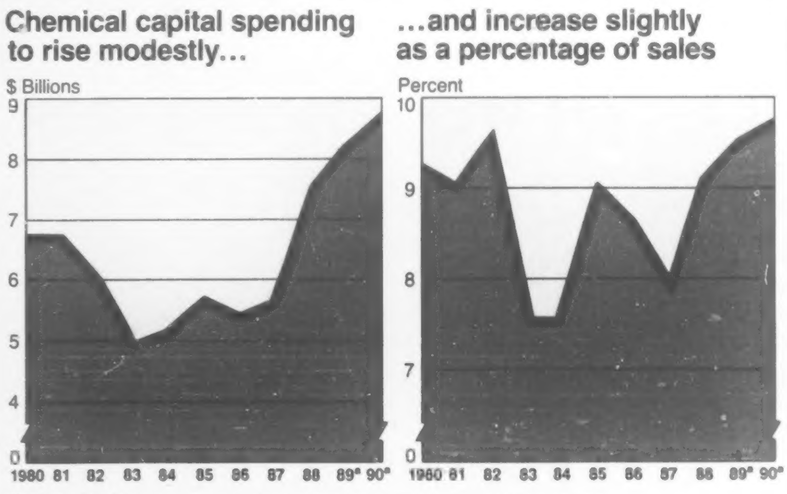
This year's survey lacks 1990 capital spending predictions from American Cyanamid, Du Pont, Monsanto, and Union Carbide. Together these four companies represented \$3.66 billion in combined capital expenditures, or 49% of surveyed companies' spending in 1988. Du Pont alone represented 27% of 1988 spending for surveyed companies. In fairness to Du Pont though, it frequently misses the deadline for C&EN's survey because its board of directors meets so late in the month that its forecast cannot be included in this December survey. The 1990 forecast thus is based on Air Products, Dow Chemical, Ethyl, W. R. Grace, Hercules, Olin, PPG Industries, and Rohm & Haas.

However, some of the large capital spending increases recorded in this C&EN survey may not be good predictors for the industry. For instance, Ethyl forecasts a 118% increase in 1990 capital expenditures to \$240 million compared with 1988, following a 27% drop in 1988 to \$110 million compared with the previous year. However, an Ethyl spokesman explains that the 1990 and 1989 numbers have been adjusted to account for the July 1989 spin-off of Tredegar Industries. Earlier numbers are not adjusted.

Dow's 24% spending rise for 1990 to \$2.1 billion compared with 1989 includes some ambitious spending plans for expansions in commodity chemicals, including a styrene plant in the U.S. and European expansions in ethylene, polyethylene, styrene, polycarbonates, isocyanates, and propylene oxide. These are ambitious given recently lower capacity utilization rates and a drop in chemical prices.

If the swings in the survey produced by Dow's and Ethyl's spending forecasts are excluded, combined expenditures planned by the six remaining companies—Air Products, W. R. Grace, Hercules, Olin, PPG Industries, and Rohm & Haas—show an average decline of 0.5%. This seems to indicate some caution in the chemical industry about the direction capital expenditures will take in 1990. Earnings in 1989 have already slowed compared with 1988. Sales were up only 3% in the third quarter of 1989 compared with the same quarter of 1988 and earnings were down 15% for the 30 major chemical companies C&EN tracks quarterly (C&EN, Nov. 13, page 8).

Given this indication of caution



Note: Combined data from 12 major chemical producers listed below. a C&EN estimates.

but also weighing in the backlog of projects to which many chemical companies are still committed, C&EN estimates that industry capital spending as a percentage of sales will be closer to 9.5% in 1989 than the 8.8% predicted in last year's survey. The 1990 figure may reach as high as 9.7%, a nine-year high, but only if spending levels remain at their present high levels.

According to a spokesman for the Houston Economic Development Council, spending in the center of the U.S. petrochemical industry remains strong. According to a survey taken by Houston Lighting & Power Co. in March, 149 projects valued at $5.5 billion are under way or scheduled in the Houston Gulf Coast region between 1989 and 1992. But it is reasonable to assume, says the spokesman, that some of those projects will be abandoned as the industry reaches overcapacity. The council, he says, does not expect to see as many projects under way in the next four years as there are currently. The only exception is Phillips 66's unanticipated capital expenditures to replace polyethylene capacity lost in the Oct. 23 explosion in Pasadena, Tex.

In fact the council is pushing to bring fabricators of end-use products into the Houston area to avail themselves of the enormous supply of raw materials available there, says the spokesman. Petrochemical producers may not be investing so heavily in their plants after 1992 if only because they will have state-of-the-art facilities in place then, says the spokesman.

Jane E. Belcher, an assistant vice president and chemical analyst with the investment research and credit rating firm of Duff & Phelps in Chicago, expects overall chemical industry capital spending to stabilize or perhaps increase "a little" in 1990 following the "significant" increase in 1989 spending. Some projects announced for ethylene expansions may have to be canceled as a result of the drop both in capacity utilization and prices, but Belcher believes the level of capital expenditures for 1990 will remain "healthy."

A healthy level of spending is justified because 1990 probably will bring only a slowdown and not a recession, says Belcher. As a result, chemical producers will be in a good position to take advantage of an upswing in the economy.

Du Pont chief economist Richard J. Stuckey says that capital spending for the chemical industry was up only 3% in constant dollars for 1989 compared with 1988. He predicts that there will be no growth in capital expenditures in 1990 for the industry. However, he notes that spending for 1988, 1989, and 1990 is at a level 60% above the second half of the 1970s in real dollars. The industry, therefore, is investing

Capital spending of surveyed companies will increase 12% next year

	1990		1989		Worldwide					Change from previous year	
$ Millions	Total	U.S.	Total	U.S.	1989 planned[a]	1988	1987	1986	1985	1990	1989
Air Products[b]	$ 600	$ 420	$ 562	$ 372	$ 550	$ 409	$ 323	$ 367	$ 392	6.8%	37.4%
American Cyanamid	na	na	400	na	350	374	268	263	203	na	7.0
Dow Chemical	2100	1155	1700	935	1650	1670	995	890	806	23.5	1.8
Du Pont[c]	na	na	na	na	na	2029	1674	1587	1515	na	na
Ethyl[d]	240	155	110	95	150	151	139	134	90	118.2	−27.2
W. R. Grace	550	na	475	na	475	418	243	199	348	15.8	13.6
Hercules	225	175	280	235	na	251	205	257	234	−19.6	11.6
Monsanto	na	na	600	450	na	590	505	520	645	na	1.7
Olin	175	na	130	na	130	147	115	128	154	34.6	−11.6
PPG Industries	450	280	575	435	500	410	426	356	452	−21.7	40.2
Rohm & Haas	395	292	385	280	350	338	222	179	159	2.6	13.9
Union Carbide	na	na	na	na	800	671	502	524	649	na	na
TOTAL	**$4735**	**$2477**	**$5217**	**$2802**	**$4955**	**$7458**	**$5617**	**$5404**	**$5647**		
ANNUAL CHANGE[e]	12%	5%	10%	24%		33%	4%	−4%	10%		

a Earliest estimate. b Fiscal year ends Sept. 30. c Excludes Conoco. d 1989 and 1990 figures adjusted to reflect spin-off of Tredegar Industries in July 1989. e Cumulative change for companies reporting. na = not available.

West German chemical giants plan spending hikes

Arriving at a composite picture of capital expenditures for West Germany's three largest chemical companies—BASF, Bayer, and Hoechst—is as difficult as obtaining one for their U.S. counterparts. The three are in as much of a quandary about the direction of the economy in 1990 as many U.S. companies. Only one of the three, BASF, provided a projection for spending plans worldwide as well as for its U.S. operations during 1990. Hoechst could only provide 1990 data for its U.S. unit, and Bayer didn't provide any 1990 data at all.

BASF forecasts its total 1990 worldwide capital expenditures at $2.6 billion, a 12% increase over year-earlier spending levels (figures are based on a conversion rate of $1.00 = 1.8 deutsche marks for both 1989 and 1990). The company projects a spending increase at less than half the rate of its 21% increase in 1989, when it figures it spent $2.3 billion. Of the two companies that provided an estimate of 1989 capital spending, BASF and Bayer collectively hiked expenditures 13% in 1989 compared with their combined spending levels a year ago.

The West German chemical companies continue to spend a greater share of their overall budget in the U.S. for plant and equipment improvements than has been their practice in spending for their worldwide operations. Of the two who could estimate 1990 plans for U.S. spending, BASF and Hoechst planned a combined 32% increase in spending for 1990. Unlike their U.S. counterparts, these two companies are increasing the level of their investment by a considerable amount; the seven reporting U.S. companies are increasing their 1990 U.S. investments a combined 5%.

Again in 1989, the three West German companies differed from their U.S. competitors in their spending patterns in the U.S. The three boosted their spending in the U.S. only 14% in 1989. In contrast, the seven reporting U.S. companies in this year's survey say they increased their 1989 spending levels a collective 24%. Apparently U.S. chemical concerns spend more in a growing economy and less in a declining economy. In contrast, their West German competitors take greater risks in a downturn for long-term goals.

	1990		1989		Change from previous year	
$ Millions[a]	Total	U.S.	Total	U.S.	1990	1989
BASF	$2555	$ 650	$2277	$ 460	12.2%	21%
Bayer	na	na	1851	333	na	4
Hoechst	na	450	na	375	na	na
TOTAL	$2555	$1100	$4128	$1168		
ANNUAL CHANGE[b]	12%	32%	13%	14%		

a $1.00 = 1.8 deutsche marks. b Cumulative change for companies reporting. na = not available.

heavily in plant and equipment improvements at current levels, he points out. Spending may in fact have to drop soon, Stuckey believes, because if current spending levels persist, the industry would have a lot of excess capacity.

Stuckey agrees with Duff & Phelps' Belcher that the economy is heading for a soft landing rather than a recession. This bodes well for sustained capacity utilization rates. For one, interest rates have eased and the Federal Reserve System has increased available dollars in the marketplace since the summer, thus making it possible to finance current capital projects. And although the leading economic indicators slipped in October, they have not slipped to levels usually seen prior to a recession. Both employment and income continue to rise, he says. A bright note, too, is that consumer confidence is still high, meaning consumers don't intend to postpone personal consumption to an extent that would harm manufacturing and retail operations, with the exception of the automotive sector.

Housing, a large customer of the chemical industry, probably will not be a big plus for the chemical industry in 1990, but neither will it be a big minus, says Stuckey. Similar to last year, exports of U.S. chemicals will continue to grow in 1990, thereby bolstering industry capacity utilization. The dollar, he believes, is still low enough relative to European and Asia/Pacific currencies to warrant further export gains by U.S. chemical manufacturers.

Capital and equipment improvements this year have ostensibly put chemical companies in a good position to prosper should the economy experience that "soft landing" in 1990. Five of eight chemical producers who provided sufficient data for comparisons actually spent more in 1989 than they originally planned. PPG Industries increased its expenditures 40% to $575 million. That figure is $75 million more than it forecast in last year's survey and well ahead of the average of 10% for the group of companies reporting 1989 expenditure plans. Air Products increased 1989 spending 37% to $562 million, $12 million more than it planned originally. Rohm & Haas also boosted spending a considerable 14% in 1989 to $385 million, $15 million more than it had predicted.

American Cyanamid invested $400 million in capital projects in 1989, an increase of 7%—below the 10% average for the group, but $50 million more than it had planned. Dow boosted its 1989 spending level a mere 2% to $1.7 billion. Still that increase represented an increase of $50 million above its original figure.

Hercules did not provide an early 1989 spending prediction. Its most recent spending figure of $280 million for 1989, however, is some 12% above its year-earlier spending level and higher than the group average.

The U.S. seemed to benefit more from capital spending efforts in 1989 than reporting companies predicted in last year's survey. Responding companies increased 1989 U.S. spending levels an average 24%, reflecting stronger market conditions during the first part of 1989 than originally supposed. In last year's survey, reporting companies planned only a 12% increase in U.S. expenditures. □

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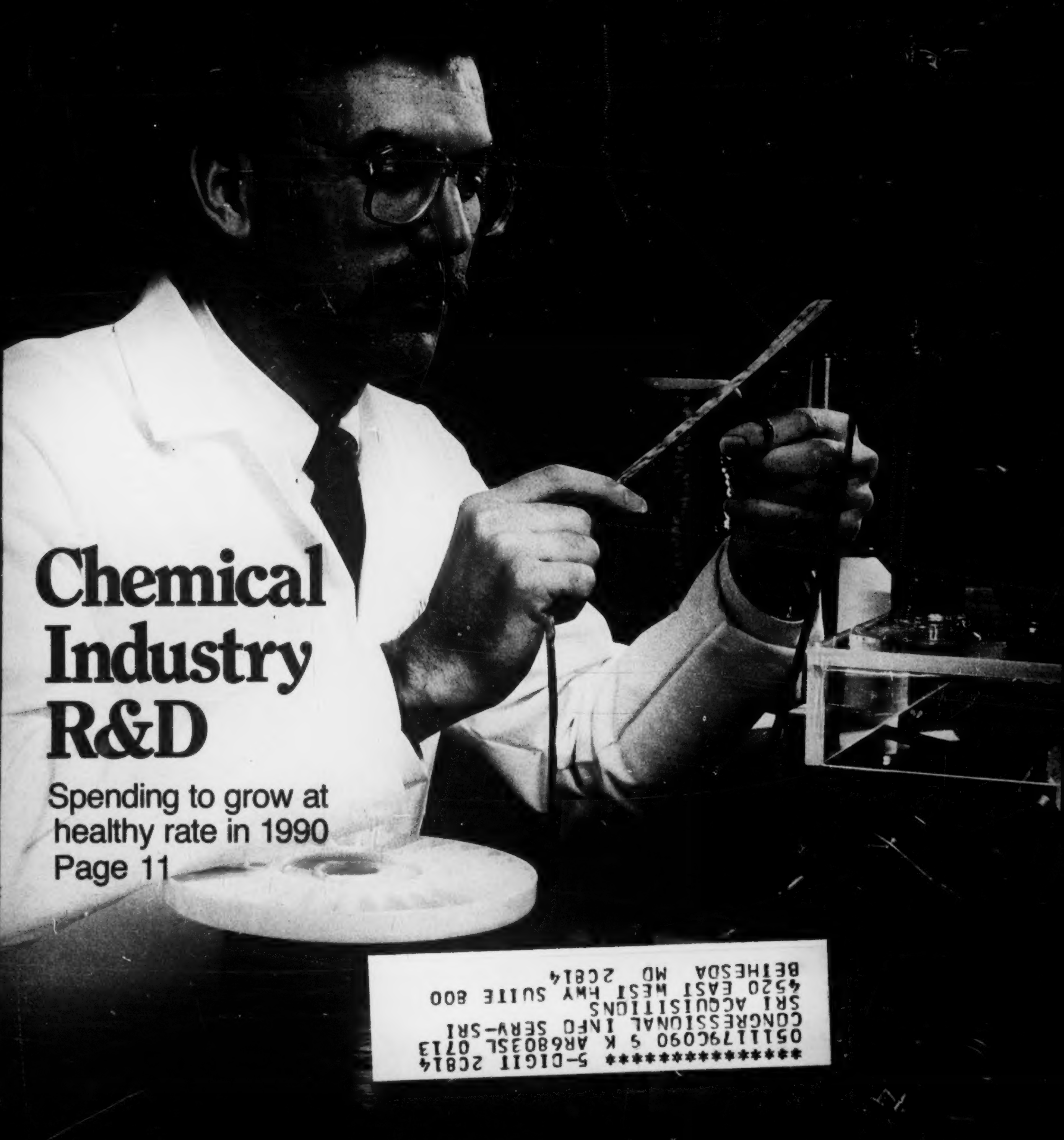
NEWS



Chemical Industry R&D

Spending to grow at healthy rate in 1990
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- **Supreme Court rules to allow EEOC to subpoena tenure evaluation files when investigating charges of discrimination.** Page 5
- **New stack gas scrubbing process effectively removes nitrogen, sulfur oxides from exhausts.** Page 5
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- **Brazil attempts to shore up its troubled fuel ethanol program with methyl *tert*-butyl ether, ethanol, and methanol imports.** Page 6

Cover: Monsanto scientist inspects copper-coated fiber as part of company's research thrust to develop new performance materials. Photo by James Visser for Monsanto

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Government

Environmental problems posing the least risk to humans or the environment are getting the most attention from EPA, study by three regional offices shows. **Page 16**

National Science Foundation's new inspector general office keeps tabs on agency programs and operations. **Page 17**

Science/Technology

More news from PACIFICHEM '89 meeting in Honolulu: Chemical modification of lignocelluloses promises improved wood-based products for materials industries; solid-state NMR benefits studies of polymers, peptides, other compounds; Japanese chemists propose mechanisms for activation and oxidative coupling of methane; continuous-flow microwave reactor speeds reactions, increases yields; synthesis of α-arylpropionic acids as anti-inflammatory drugs achieved; new approach to synthesis of bimetallic cluster catalysts devised; inorganic membrane reactor uses oxygen from air in oxidative coupling of methane; copper-exchange zeolites are promising catalysts for nitric oxide decomposition; polyethylene-glycol-modified protein on verge of approval as drug. **Page 19**

ACS News

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Major U.S. chemical companies plan a modest 7% increase in R&D spending this year, up from 6% in 1989, according to a recent C&EN survey. Page 11

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LETTERS

Ammonia does burn

SIR: In a Government Concentrates column (C&EN, Aug. 7, 1989, page 23), a note was presented that ammonia has been classified as a "nonflammable gas" by the Department of Transportation.

That's odd, because liquid ammonia was the fuel, along with liquid oxygen, for the National Aeronautics & Space Administration's X-15 rocket research aircraft of the 1960s. The oxygen and ammonia were ignited by a high-energy spark plug. I'm sure propane, etc., are more easily ignited, but the stuff does burn.

Ernest J. Tews
South Plainfield, N.J.

Higher education ignored

SIR: The "1990 Employment Outlook" (C&EN, Oct. 23, 1989, page 22) provided not only an excellent overview of the chemistry and chemical engineering fields, it highlighted some deep problems that the government has exacerbated and that the scientific community has ignored.

Nearly one year ago to the day, C&EN published responses of George Bush and Michael Dukakis to queries about science and technology policy in "Presidential Candidates Give Views on Science Issues" (C&EN, Oct. 17, 1988, page 7). I wrote to the editor that as a graduate student I did not believe the rhetoric of either. One year later, it seems that I have been vindicated. Bush probably will not double the National Science Foundation's budget within five years. Although he did convene an "education summit," he made no commitments and totally ignored higher education. Similarly, Dukakis has been defanged politically by the collapse of the "Massachusetts Miracle." As a result, he has started to dismantle the state's higher education system, one of the few bright spots in this state's reputation and economy. To make matters worse, he has removed, inadvertently, state income tax exemptions for graduate student stipends and employer-provided education assistance. Due to the depth of the fiscal crisis, the income tax rates have been increased 15%.

Graduate students have been hurt by stipends that have failed to keep up with inflation (especially that in Boston) by the recently imposed federal income tax on stipends after the Tax Reform Act of 1986, and most recently by the state income tax on stipends. We have seen real income decrease precipitously in the past five years. Starting salaries for B.S. degrees in chemistry and chemical engineering are double and treble, respectively, graduate student stipends. Is it so surprising that NSF projects Ph.D. deficits of 14,000 at current stipends and 7800 at higher stipends (whatever that means) by the year 2006? Is it so surprising that industry is increasing university research funding when cost and proprietary rights differentials between graduate students and industrial chemists and chemical engineers are growing?

Educational crises exist at all levels of education in the U.S. and have profound implications for this country's future. Elementary and secondary education receive much attention and rhetoric, but even if these are corrected, who is going to educate future college and graduate students? University faculty, not to mention several scientific journals, have been disturbingly quiet about the effects of the Tax Reform Act of 1986 and the Technical Amendments Act of 1988 on graduate student enrollment and faculty recruitment. Do they think that as long as they got theirs, what happens to us does not matter? Such an attitude, if it exists, is not only selfish, it is extremely myopic. Moreover, it threatens to cannibalize higher education.

David Wagger
Cambridge, Mass.

Chemistry graduate students

SIR: I wish to respond to recent letters, as well as the letter by Dennis Sardella (C&EN, Nov. 20, 1989, page 3) concerning the lack of interest in sciences among American students. As a graduate student, it is quite obvious to me why there is not a great interest in careers in science, specifically chemistry, at the graduate and undergraduate level. Although I find my research very interesting and challenging, I still find myself and my coworkers muttering, "What am I doing here?"

The major reason for this is not a lack of interest, but a lack of incentive. Students are able to obtain degrees in law, medicine, dentistry, and management in much less time and with less work than in the less lucrative field of chemistry. Many of these people will have starting salaries that are not attainable by chemists even after many years as industrial chemists—not to mention the poor starting salaries for untenured faculty.

I have been in graduate school now for more than three years and I have no idea how much longer I will be a graduate student or whether I will ever

Chemical Industry R&D Spending Continues To Climb

Nine major chemical firms plan 7% boost in research expenditures in 1990, up from 6% increase for same companies last year

Marc S. Reisch,
C&EN Northeast News Bureau

Major U.S. chemical and diversified companies plan a healthy increase in research and development spending in 1990. According to a recent survey by C&EN, R&D spending for nine chemical firms will rise 7% from 1989, up from a 6% increase for the same nine firms last year.

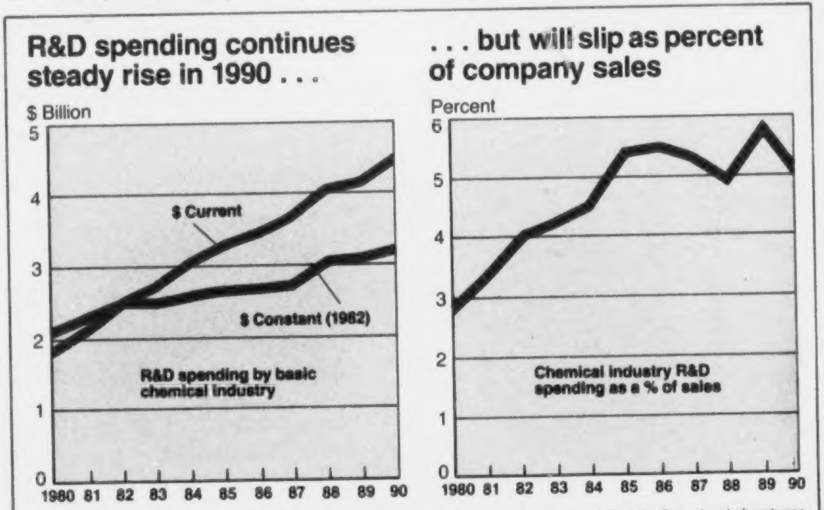
From a different survey, the Chemical Manufacturers Association projects a 5% R&D spending increase in 1990 for chemical companies with sales under $1 billion and a 7% rise for firms with sales over $1 billion—a finding in close agreement with C&EN's projection this year.

However, although CMA projects 1989 R&D expenditures rose 10% or more from the previous year, C&EN's recent survey finds that companies spent less on R&D in 1989 than they originally anticipated a year ago. Last year, 10 reporting companies anticipated increasing R&D expenditures 9% over 1988 (C&EN, Jan. 16, 1989, page 15)—a spending increase not far off CMA's 10% increase. However, in contrast, C&EN's survey this year finds that 10 responding companies increased 1989 expenditures only 4%. In constant dollar terms, based on Battelle Columbus Laboratories' cost of research and development index for all industry, that marked a mere 2% increase in research expenditures in 1989 in contrast to the 7% increase planned a year ago.

If, as CMA asserts, R&D expenditures are an important key to the international competitiveness of the U.S. chemical industry, why does it appear, according to C&EN's survey, that R&D was not so well supported in 1989 as first anticipated? And, although companies project a healthy 1990 increase in expenditure levels, will they revise their current rosy spending levels downward when the numbers start coming in next year at this time?

The answers may have partly to do with the availability of new scientists entering the job market. In fact, chemical companies may not have been able to spend the money they had budgeted to hire new scientists in support of their R&D programs, particularly in the early part of 1989 when the level of sales for the industry continued to bode well for the industry's long-term health. According to the National Center for Education Statistics, fewer bachelor's degrees in chemistry and chemical engineering were awarded in 1987 (the latest year for which data are available) than were awarded in the early years of the decade (C&EN, Aug. 21, 1989, page 55). And although the number of masters and Ph.D.s awarded in chemistry and chemical engineering have either remained stable or increased slightly, the pool of graduating chemists and chemical engineers in all degree categories has declined from 22,668 in 1980 to 20,039 in 1987.

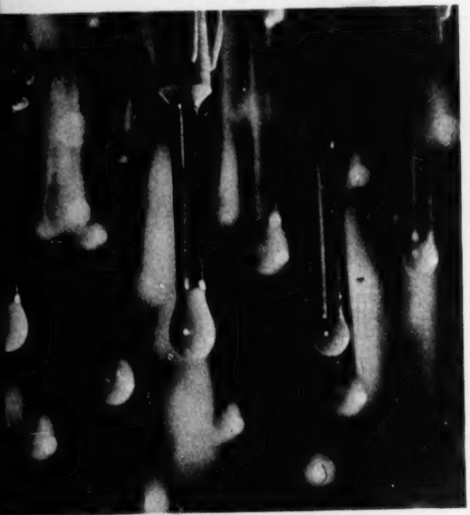
At the same time as the pool of graduating chemists and chemical engineers decreased, the National Science Foundation notes that the annual rate of retirement of Ph.D. scientists and engineers has edged up gradually and that in 1987 over one half of doctoral scientists and engineers were 45 years of age or older (C&EN, June 12, 1989, page 17). Although the number of R&D scientists in the chemicals and allied products category has increased from 51,400 in 1980 to 73,000 in 1987, according to NSF (C&EN, Aug. 21, 1989, page 50), industry has to compete for a declining population of qualified personnel who may also



R&D spending continues steady rise in 1990 . . .

. . . but will slip as percent of company sales

Note: For 12 chemical companies listed on page 13. **Sources:** C&EN surveys and estimates, Battelle Columbus Laboratories



W. R. Grace's new biological fungicide, being prilled here, is aimed at soil-borne plant diseases

choose to enter either academia or government research.

Thomas Regino, manager of technology assessment for Kline & Co., a Fairfield, N.J.-based consulting firm, warns that chemical companies can expect spot shortages of available scientists to continue in the next decade. Regino and his firm have been working on an as yet unfinished American Chemical Society survey, "Evolution within the Worldwide Chemical Community." As part of that survey, he finds that U.S. "chemical companies hire talent on an as-needed basis. There is no master plan we can detect for hiring scientists who will be needed at major chemical companies."

Another possible reason for the apparent slowdown in 1989 R&D spending compared with earlier projections may have to do with the slowdown of the economy in the latter part of 1989. Management will, in fact, pull back the level of its R&D expenditures when industry appears to slow and increase it as the economy improves. The most vivid example occurred in the early part of the past decade when the most recent recession pushed R&D as a percentage of future-oriented expenditures (capital expenditures plus R&D expenditures) as low as 19% in 1980, compared with a high of 40% in 1987 when more favorable economic conditions prevailed, and to 34% in 1989.

A downward revision in R&D expenditures in 1990 may still be seen when C&EN again reviews the numbers next year if the current slowdown continues or worsens. The good news, however, is that the chemical companies surveyed still plan nominal and real increases in R&D. By comparison, a survey of the same group forecasts capital expenditures up 12% in 1990 compared with 1989. Adjusting for two unusual exceptions, however, six out of eight reporting companies show an average nominal decline of 0.5% in 1990 capital expenditures (C&EN, Dec. 18, 1989, page 9). Factoring in inflation, the outlook for capital expenditures appears even worse.

Economic factors also are an important element in just where research is conducted. Though C&EN's R&D survey does not break out how much is spent in the U.S. as opposed to spending abroad on R&D, it's true that the trend toward globalization has encouraged U.S.-based companies not only to invest overseas but also to set up research efforts there. As U.S. companies gain position in other countries, they may be tempted to set up more R&D ventures there to serve local customers' technical requirements, and also to take advantage of one or another country's perceived advances in a developing specialty or its local pool of scientists.

In an attempt to preserve a U.S. margin of competitiveness with research abroad, the Council on Research & Technology (CORETECH)—a coalition of over 165 companies, universities, research institutions, and trade associations—has organized to preserve, among other things, a 20% federal R&D tax credit to companies for increases in qualified R&D expenditures. The credit was first established as part of the Reagan Administration's tax package in 1981.

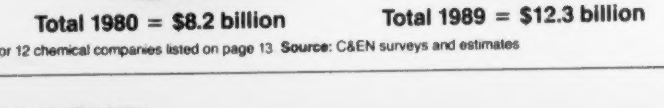
According to Kenneth R. Kay, CORETECH's executive director and a partner with the law firm of Preston, Gates, Ellis & Rouvales Meeds, Washington, D.C., Congress did extend the tax credit to the end of 1990 after some uncertainty late last year resulting from U.S. budgetary considerations. Kay says the group, which includes pharmaceutical, biotechnology, chemical, and other industry members, hopes to see the credit made a permanent part of U.S. tax law.

With more than half of surveyed companies forecasting double-digit increases in R&D spending for 1990, a federal tax credit extended at least through this year, and Battelle's forecast for industry R&D inflation of 2.4% for 1990, the chemical industry's R&D efforts this year could get a real boost. Among chemical companies surveyed by C&EN, W. R. Grace plans the biggest increase in R&D spending with a budget at $145 million, 11.5% above its 1989 spending level. The 1990 increase follows a 9.2% increase the year before.

Dow Chemical plans the second biggest gain in 1990, with its R&D funding rising 11.4% to $950 million. That increase follows a hefty 10.5% rise the year before when the company figures it spent $853 million on R&D.

Also planning a double-digit increase in R&D funding is American

R&D nearly doubles as percent of future-oriented spending



Note: For 12 chemical companies listed on page 13 **Source:** C&EN surveys and estimates

Several companies project double-digit R&D increases for this year

$ Millions	Planned 1990	Actual 1989	Planned 1989	1988	1987	1986	1985	1984	Change from previous year 1990	Change from previous year 1989	R&D spending as % of sales 1989	R&D spending as % of sales 1988
CHEMICAL COMPANIES												
Air Products[a]	$ 71	$ 71	$ 72	$ 72	$ 57	$ 61	$ 51	$ 44	0%	−1.4%	2.8%	3.0%
American Cyanamid	450	405	385	365	314	278	251	232	11.1	11.0	8.3	7.9
Dow Chemical	950	853	850	772	670	605	547	507	11.4	10.5	4.8	4.6
Du Pont[b]	1380	1320	na	1319	1223	1156	1144	1097	4.5	0.1	6.1	6.5
Ethyl[c]	65	59	58	53	50	47	47	40	10.2	11.3	2.7	2.5
W. R. Grace	145	130	132	119	107	94	92	81	11.5	9.2	2.1	2.1
Hercules	na	na	na	74	74	71	76	72	na	na	na	2.6
Monsanto	na	600	615	648	615	596	470	370	na	−7.4	6.8	7.8
Olin	65	65	65	58	62	56	53	52	0	12.1	2.7	2.5
PPG Industries	250	250	250	227	227	204	176	150	0	10.1	4.2	4.0
Rohm & Haas	180	170	185	156	142	133	124	109	5.9	9.0	6.3	6.2
Union Carbide	na	na	193	159	159	148	275	265	na	na	na	1.9
TOTAL	**$3556**	**$3923**	**$2805**	**$4022**	**$3700**	**$3449**	**$3306**	**$3019**			**5.9%**	**4.9%**
ANNUAL CHANGE[d]	**7%**	**4%**		**9%**	**7%**	**4%**	**10%**	**12%**				
DIVERSIFIED COMPANIES												
Allied-Signal[e]	650	600	600	647	400	360	298	258	8.3	−7.3	4.8	5.4
Arco Chemical	na	na	44	39	29	32	29	29	na	na	na	1.4
Eli Lilly	na	600	600	500	466	427	370	341	na	20.0	13.9	12.3
FMC	155	148	na	144	132	146	149	121	4.7	2.8	4.2	4.4
Merck & Co.	na	755	na	650	566	480	426	393	na	16.2	12.0	10.9
Morton International[e,f]	50	38	na	35	31	29	34	28	31.6	8.6	2.7	2.9
Schering-Plough	370	330	na	298	251	212	189	173	12.1	10.7	10.5	10.0
TOTAL	**$1225**	**$2471**	**$1244**	**$2313**	**$1875**	**$1686**	**$1495**	**$1343**			**7.9%**	**7.2%**
ANNUAL CHANGE[d]	**10%**	**9%**		**23%**	**11%**	**13%**	**11%**	**13%**				

[a] For fiscal year ended Sept. 30. [b] All figures exclude Conoco. [c] 1989 and 1990 figures adjusted to reflect spin-off of Tredegar Industries in July 1989. [d] For those companies reporting. [e] Includes all company-financed R&D, but excludes contract R&D. [f] Fiscal year ended June 30. Figures adjusted to 1986 in order to reflect division of Morton Thiokol into Morton International and Thiokol Corp. in July 1989; 1984 and 1985 figures are for Morton Thiokol. na = not available.

Cyanamid, with an 11.1% increase to $450 million. That increase follows a similarly large 11% increase the previous year when the company spent about $405 million, 5% more than it originally planned to spend when it participated in last year's survey.

Ethyl plans a large increase in 1990 R&D spending, too, with a preliminary budget of $65 million, up 10.2% from its year-earlier level. Its 1989 R&D budget was similarly large, up 11.3% from the year earlier to $59 million. Ethyl's 1989 and 1990 numbers reflect the spin-off last summer of Tredegar Industries. Earlier years include the aluminum, plastics, and energy groups now no longer part of Ethyl's business. With R&D spending levels at about 2.7% of sales in 1989 and 2.5% of sales in 1988, Ethyl is still on the low end of R&D investment in its businesses compared with the group average of about 5.9% in 1989 and 4.9% in 1988.

Falling below the average increase for the nine chemical companies is Rohm & Haas, which plans to spend $180 million in 1990, up only 5.9% compared with the $170 million it spent in 1989, which was up 9% compared with 1988. Despite the 1990 slowdown in R&D expenditures, Rohm & Haas still rises above the average for the group in terms of R&D spending as a percentage of sales, with 6.3% of sales devoted to R&D in 1989 and 6.2% of sales devoted in 1988.

Du Pont plans a 4.5% increase in R&D spending for 1990, although that increase is on a very large base. The company will spend $1.38 billion in 1990, compared with $1.32 billion in 1989. Its 1989 spending was only 0.1% above that in 1988.

Three companies say they plan no increase or decrease in R&D spending for 1990—Air Products & Chemicals, Olin, and PPG Industries. In contrast, in 1989 Air Products decreased its spending 1.4% from 1988, as Olin increased its spending 12.1% and PPG increased its spending 10.1%.

Hercules, Monsanto, and Union Carbide were unable to provide an early estimate of their R&D spending for 1990. Of the three, only Monsanto could estimate that in 1989 it spent $600 million on R&D, down 7.4% from 1988.

Among diversified manufacturers, four companies responding to the survey—Allied-Signal, FMC, Morton International, and Schering-Plough—plan to increase their R&D budgets an average of 10% in 1990. Their figures include internally generated R&D projects only and not government contracts.

Morton International reported the largest increase in R&D for the group of diversified manufacturers. Morton International figures from 1986 to the present exclude the aerospace business previously a part of Morton-Thiokol. As a result of the spin-off of Thiokol Corp. in July last year, two renamed firms now exist. As Morton International focuses on its specialty chemicals, salt, and inflatable restraint systems, it now devotes about 2.7% of sales to R&D spending for 1989, following a 2.9% level in 1988. Those figures are up from the 2% Morton-Thiokol reported in last year's survey. □

Mass Terminations of Chemists Hold at Relatively Low Level

Although it will be of little comfort to chemists who are still losing their jobs because of corporate restructurings and reorganizations, the lull in mass terminations of chemical professionals is apparently continuing. The latest report on such terminations by ACS's Committee on Professional Relations (CPR), the first in more than a year, covers five such incidents involving a total of about 45 chemical professionals.

The previous report (C&EN, Dec. 19, 1988, page 42) also covered only five terminations involving about 40 terminees. From 1979 through 1988 there had been two reports per year. These typically each covered about 10 terminations and, in some cases, involved a total of more than 200 terminees.

CPR states it is "pleased to note that the relatively low number of multiple terminations reported for investigation continues, as does the relatively low number of chemical professionals involved."

However, the committee continues to be distressed about the treatment of older chemists. The committee points out that a high percentage of the chemists and chemical engineers still losing their jobs in mass terminations have more than 10 years of service.

CPR defines a mass termination as a situation in which an employer terminates within a six-month period three or more chemical professionals for reasons other than continuing evidence of previously documented inadequate performance, completion of a contract, or cause.

The committee's latest report is the 29th in a series dating back to 1974. Each compares the treatment of those being terminated with standards contained in ACS's Professional Employment Guidelines (PEG). These standards cover advance notice, severance pay, assistance in finding new employment, pension vesting, length of terminees' service, and extension of protection plans. They were complied with an average of 47% of the time in the latest report. This is essentially the same as the 48% average for the previous 28 reports.

The terminations covered by the latest report occurred at General Mills, Koppers, Petrolite, Tennessee Valley Authority, and UOP between June 1988 and April 1989. They involved from seven chemical professionals at both General Mills and UOP to 14 at Petrolite.

CPR seeks information on terminations from terminees themselves as well as from employers and ACS local sections. The committee also welcomes information from individual society members. All five employers involved provided at least partial information for the latest report. The St. Louis and Wilson Dam local sections assisted CPR by helping to identify terminees.

Of the six PEG termination standards, those concerned with pension vesting and assistance in obtaining new employment are generally complied with very well. They were both met in all cases in the latest report. The standards on advance notice and the extension of protection plans have been complied with in 40% and 49%, respectively, of all terminations to date.

However, it is still the exceptional employer that complies with the

Employer compliance with ACS employment guidelines

These employers provided information	Approximate number of employees separated	Advance notice	Severance pay	Assistance	Pension vesting	Employee service	Protection plans
General Mills (Minneapolis, Minn.)	7	▨	▨	☐	☐	■	▨
Koppers/Beazer plc (Monroeville, Pa.)	9	▨	☐	☐	☐	■	▨
Petrolite (Webster Groves, Mo.)	14	■	▨	☐	☐	■	■
Tennessee Valley Authority (Muscle Shoals, Ala.)	8	☐	▨	☐	☐	■	■
UOP, Tarrytown Technical Center (Tarrytown, N.Y.)	7	☐	▨	☐	☐	■	☐

☐ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard, but average experience better than "substantially below" criterion.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than two weeks.
- Assistance—no assistance rendered.
- Severance pay—less than one week per year of service.
- Employee service—more than 40% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans.

ACS guidelines

Advance notice. Four-week minimum.

Severance pay. Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.

Assistance. Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.

Pension plan vesting. Full vesting after five years' service.

Employee service. Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.

Employee protection plans. Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination, at same rate of contribution as before. Employee would have additional 31-day grace period.

standards covering severance pay and the firing of older, more experienced chemists. The severance pay standard calls for a minimum of two weeks' pay per year of service. Only 22% of employers covered by all 29 reports have complied. However, compliance has been improving. It has averaged 31% since 1982.

The PEG standard on employee service states that chemical professionals with a minimum of 10 years' service should not be terminated, except for inadequate performance or cause. Long-term compliance has been at 23%. But in recent years it has been getting considerably worse. It has averaged only 10% since 1985. All five employers in the latest report violated this standard. In four of these cases almost all the terminees apparently had more than 10 years of service.

Copies of termination reports as well as a summary list of all terminations are available on request from the American Chemical Society, Office of Professional Services, 1155—16th St., N.W., Washington, D.C. 20036.

Michael Heylin

Colloid and surface chemistry fellowship

Henkel Corp. is sponsoring an annual two-year graduate fellowship award in colloid and surface chemistry, to be administered by the ACS Division of Colloid & Surface Chemistry.

Each fellowship will consist of $20,000 each year for two years to be used entirely for the fellow's stipend, scientific travel, and other direct research costs. The award is intended to support outstanding graduate students during their final two years (preferably, their third and fourth years) of doctoral thesis research. This research must represent a significant advance in understanding fundamental chemical processes in interfacial systems. Applicants must be enrolled in a full-time graduate program leading to a Ph.D. degree at an accredited university within the U.S.

Applicants must independently prepare a proposal based on their thesis research plans. Documents should contain

- a 100-word research proposal abstract;
- a detailed research proposal (eight double-spaced pages maximum) with a background and literature survey, specific project goals, methods and critical scientific decision points, and required equipment and supplies;
- a brief (one to two paragraph) statement of career goals and how this fellowship can contribute to achieving these goals;
- a project budget delineating the distribution of funds among stipend, travel, equipment, supplies, and other direct costs along with a letter of budget approval from the department chairman (the funds may not be used for overhead costs, or tuition and fees, which must be waived by the university);
- a curriculum vitae, with reprints of any publications, and undergraduate and graduate transcripts; and
- letters of recommendation from the research adviser and two additional references (research adviser to include a statement of available research facilities).

For funding to commence in the fall semester 1990, three copies of the above documents must be submitted by the deadline of Feb. 1 to the selection committee chairman, David I. Devore, Henkel Corp., 300 Brookside Ave., Ambler, Pa. 19002, phone (215) 628-1586. □

Award nominations for ag or food chemistry

The ACS Division of Agricultural & Food Chemistry is sponsoring awards to encourage undergraduate and graduate research in the fields of agricultural and food chemistry and to recognize with these awards students doing outstanding research in these areas.

The undergraduate and graduate awards provide $250 and $750 cash, respectively, and a maximum of $750 for expenses for a student to attend the fall meeting of the American Chemical Society to present a paper on his or her research and to receive a certificate in recognition of this outstanding achievement in undergraduate or graduate research.

To be eligible for the undergraduate award, the applicant must be a junior or senior at the time he or she applies and doing research in the area of agricultural or food chemistry in the U.S.

To be eligible for the graduate award, the applicant must have completed at least one and one half, and preferably two, years of graduate study in any department at the time of application, provided the research is mainly chemical and agricultural or food related.

Applications must be received on or before Feb. 15, so that the winner(s) may present their research talks at the fall ACS meeting to be held in Washington, D.C., Aug. 26–31.

For further details, address all inquiries to Harold E. Swaisgood, Department of Food Science, North Carolina State University, Box 7624, Raleigh, N.C. 27695-7624, phone (919) 737-2968. □

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ACS national meeting in Boston
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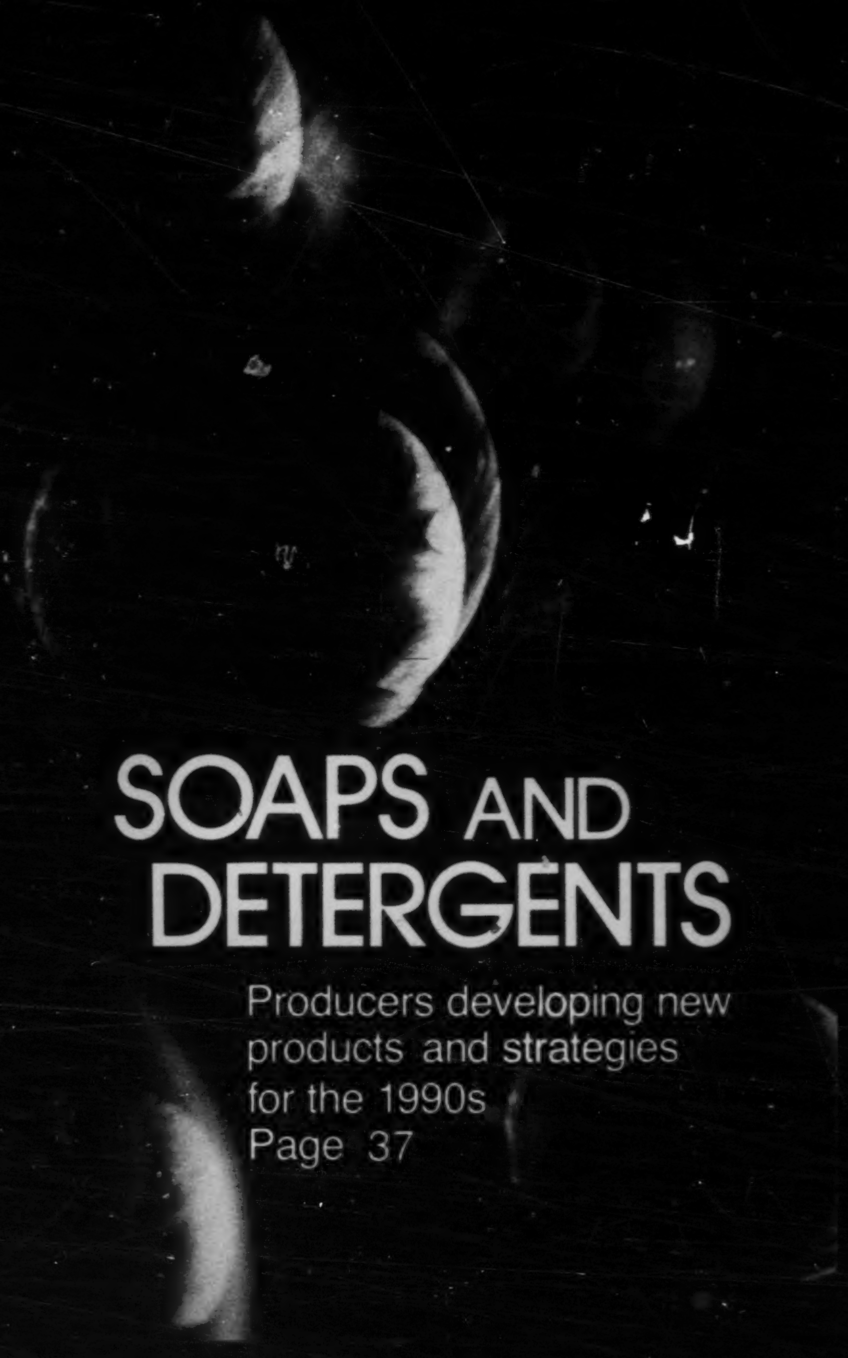
JANUARY 29, 1990

CHEMICAL & ENGINEERING

NEWS



SOAPS AND DETERGENTS

Producers developing new
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for the 1990s
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CHEMICAL & ENGINEERING NEWS

JANUARY 29, 1990

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- **Hercules will report a net loss in 1989 because of unrecoverable cost overruns and sales that didn't materialize of its rocket motors.** Page 5
- **Bills to boost the Environmental Protection Agency to membership in the Cabinet have been endorsed by President Bush.** Page 5
- **An appeals court has overturned the conviction of three Chicago company executives for involuntary manslaughter in the work-related death of an employee.** Page 6
- **Action to head off the looming shortage of technical Ph.D.s was urged recently by both the Secretary of Education and the Association of American Universities.** Page 6

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Business

ICI Americas is pushing hard in effort to fulfill its U.K. parent's goal of deriving 30% of its global chemical sales from U.S. market. **Page 13**

Government

Implementation of Chemical Diversion & Trafficking Act raises issues that industry and government are working on together. **Page 18**

Science Policy

White paper on Japanese science and technology policy makes obvious U.S.'s less focused approach. **Page 21**

Science/Technology

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Chemical & Engineering News

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LETTERS

High-strength fiber

SIR: Reading Stu Borman's article on the new high-strength fiber, Spectra (C&EN, Oct. 9, 1989, page 23), currently under development at Allied-Signal, I am surprised to see no reference to the original inventors of ultradrawn polyethylene. The foundation for the gel-spinning of ultrahigh molecular weight polyethylene was laid in the 1970s at the University of Groningen, the Netherlands. The commercial production of the so-called Dyneema fiber at DSM was taken up in 1983 after the granting of a patent to P. J. Lemstra (Technical University Eindhoven) and P. Smith (currently at the University of California, Santa Barbara).

In the perspective of the recent dramatic struggle between Akzo and Du Pont on the Twaron-Kevlar fiber, one would expect U.S. science journalism to be more respectful of European innovations.

Albert H. Alberts
Technical University Eindhoven
The Netherlands

Procedure for cyanide waste

SIR: J. A. Singmaster (C&EN, Nov. 6, 1989, page 2) again argues against the safety of the procedure for the laboratory destruction of cyanide waste by hypochlorite solution that is in the National Research Council's "Prudent Practices for Disposal of Chemicals from Laboratories." There are flaws in his argument.

W. L. Faust's article in *Science* does not say that cyanate and thiocyanate salts are explosive; it points out that metal salts of azides, fulminates, isocyanates, and isothiocyanates are similar in chemical and crystal structure and then says that explosives included among these are azides and fulminates.

Cyanate is not reduced to cyanide by ferrous ion—nor by hydrogen iodide, sulfur dioxide, or sodium sulfide [Williams, "Cyanogen Compounds," Edward Arnold, London, page 68 (1948)].

The reaction of cyanate with hypochlorite to form nitrogen is sensitive to pH and temperature. For instance, at 25 °C it is rapid at pH 4 to 8; very slow at pH 11 to 12. Singmaster may not have been working under the right conditions to get nitrogen. Whatever caused the acrid odor that he observed was probably not $ClNCO$, which is unstable even at 0 °C and is rapidly hydrolyzed by water [Nachbaur and Gottardi, *Monatsch. Chem.*, **97**, 115 (1966)].

Hence the conclusions of John Pilznienski (C&EN, April 22, 1985, page 2) and Blaine McKusick (C&EN, May 13, 1985, page 2) in response to Singmaster's first letter (C&EN, Feb. 18, 1985, page 2) are still valid. Cyanates do not detonate, do not isomerize to fulminates, and have a limited lifetime in water. The NRC procedure for disposing of laboratory cyanide waste is safe and appropriate.

Blaine C. McKusick
Wilmington, Del.
John F. Pilznienski
Kolene Corp., Detroit

Attacks on chemical industry

SIR: James Sims is right: The American Chemical Society must get its head out of the sand (C&EN, Oct. 23, 1989, page 3). As a 30-plus-year member of the society it is disconcerting to see how ineffectually the society meets the attacks upon the chemical industry. Entering the political arena to prevent the industry's being legislated out of existence is fine. However, chemists need to reach a consensus on some serious problems and misunderstandings as the first order of business. Why?

The society is being outmuscled by well-financed groups who have become our spokesmen to the media and Congress—strictly by default. Chemists have a record of communicating poorly, or not at all. Where are we missing the boat? Here is where I think that the society could help: It must promote discussion on the most relevant environmental issue today. That is zero-risk and safety, for all issues converge here.

Regarding zero-risk, traces of Alar on apples created a national furor; as a suspected carcinogen it was dangerous to children. This episode is a paradigm of the mind-set of all who insist that all traces of supposedly toxic chemicals must be eliminated. To a scientist, what is wrong with this idea? First, present day analytical methods are so powerful that the minutest traces of a substance can be detected; traces mean nothing, of themselves, unless related to safety (toxicity) of that substance. Second, what about the phenomenom of hormesis: The rather surprising idea that small amounts of a nonnutrient (even toxins, radiation) may be beneficial to humans? The principle is supported by some outstanding scientists, including B. L. Cohen, T. D. Luckey, and P. Beckmann, among others. Clearly, there would be no immunity in *Homo sapiens* if all traces of disease-causing bacteria and viruses were eliminated, and risks of exposure were zero!

On the issue of safety, why can't we be completely safe? First, our methods

Continued on page 88

Chemical Industry, Drug Agency Sort Out Chemical Diversion Issues

House hearings on recently implemented chemical diversion and trafficking law examine its workability as well as its effectiveness

David J. Hanson, C&EN Washington

The government's efforts to curtail the use of illegal drugs in the U.S. have taken a variety of forms. Most visible, of course, has been the seizure of large quantities of cocaine from ships, planes, and warehouses where drug traffickers have hidden their illegal goods. A less visible effort began late last year to dry up the supplies of these drugs, particularly cocaine, by denying the drugmakers the chemicals needed to extract and purify their product.

The Chemical Diversion & Trafficking Act of 1988, which went into effect this past fall, is designed to monitor and halt the flow of legitimate chemicals into illegal uses. Still in the process of being fully implemented, the law requires chemical manufacturers, importers, or exporters of 12 chemicals that are precursors to illegal drugs or of eight chemicals that are considered essential to the making of those drugs, to maintain records on all transactions involving these compounds. The law will be used to track chemical diversions domestically and internationally. Most of the emphasis so far has been on Latin America because it may pose a tougher problem.

Companies are also supposed to report suspicious orders and provide advance notice to the Drug Enforcement Administration of imports and exports of these chemicals. The law gives the U.S. Attorney General the authority to suspend any imports or exports he or she determines may be diverted to illegal drug manufacturing.

The U.S. chemical industry has been trying to work closely with DEA officials to make sure the law is both workable and effective. Faced with the reality that some products of U.S. companies are being used to make cocaine in South America, the industry wanted to take at least partial responsibility for stopping this trade. But as noted during the course of hearings held by the House Select Committee on Narcotics Abuse & Control to determine how the law is working out in practice, several issues have arisen that are worrisome to the chemical industry.

As noted by Chemical Manufacturers Association spokesman Gene Browning, manager of product regulatory operations for the silicon plastics division of General Electric, these problems include difficulty in meeting DEA's requirements for identifying "regular customers," an unexpected requirement for businesses to keep receipt records, and an overall lack of clear interpretation and guidance from DEA for the regulated companies.

A basic problem is just how much U.S. product is being used to make cocaine in South America. DEA operations assistant administrator David L. Westrate says: "Although it is impossible to determine the exact percentage of U.S.-made chemicals that are used in the manufacture of cocaine, trade records and intelligence reports indicate that the U.S. is by far the largest exporter of chemicals to Latin America." DEA has stated in the past that as much as half the chemicals used in cocaine manufacture could have been diverted from U.S. shipments.

Only a few figures on chemicals seized in South America are available from DEA. In Westrate's testimony before the House committee, he states that from Jan. 1 to Sept. 18, 1989, "chemical seizures by the Colombian National Police included more than 620,000 gal of ether, almost 850,000 gal of acetone, nearly 120,000 gal of sulfuric acid, one-half million gal of methyl ethyl ketone, and more than 160,000 kilos of potassium permanganate." Westrate mentioned the discovery of several clandestine laboratories in Colombia, including one that had a 30-foot camouflaged exhaust tower and six 22,000-gal storage tanks hidden under a road. The point he was making, of course, is that the drugmakers have set up a major operation that requires a large volume of chemical supplies.

The chemical industry, represented by CMA and the Synthetic Organic Chemical Manufacturers Association, does not dispute that some chemicals may end up in the hands of drugmakers, but there is some disagreement about the quantity U.S manufacturers are responsible for. CMA, faced with DEA's claims of wholesale diversion of chemicals to cocaine production, did its own analysis of U.S. chemical exports to Latin America using data from the U.S. Commerce Department. General Electric's Browning stated: "Although we have not assessed the volume of legitimate uses in Latin America, the current export levels of essential chemicals appear largely consistent with legitimate end uses. Overall, the trade data tend to indicate that smaller volumes of U.S.-origin essential chemicals are being shipped to Colombia, and therefore are not generally a source of the problem in that country." In general, the industry belief is that DEA has overstated U.S. companies' contribution to cocaine production.

U.S. exports to Latin America small quantities of chemicals used for cocaine production

Millions of lb[a]	Bolivia	Brazil	Chile	Colombia	Panama	Peru	Venezuela	World
Acetone	0.03	7.85	1.82	4.67	0.62	0.09	8.89	220.98
Acetic anhydride	0	0	0	0	0	0	0	0
Benzyl chloride	na	na	na	na	na	na	na	na
Ethyl ether	0	0	0	0	0	0	0	0.46
Hydriodic acid	0	0.39	0.02	0.21	0.07	0.02	2.83	64.96
Methylamine	0	0.24	0.12	0.69	0	0	0.32	17.24
Methyl ethyl ketone	0	4.12	2.47	12.80	0.08	0.33	8.69	56.93
Potassium compounds	0.44	0.33	0.26	0.10	0	0.04	0.04	26.18
Toluene	0.02	0.02	2.12	0	1.73	1.10	5.30	75.97
TOTAL	**0.49**	**12.95**	**6.81**	**18.47**	**2.50**	**1.56**	**26.07**	**462.72**

a 1988. na = not available. **Source:** Chemical Manufacturers Association

A prime example appears to be potassium permanganate. This oxidizing agent is one of the regulated chemicals. DEA says it seized more than 12 million lb of the chemical during 1988 in Colombia and other cocaine-associated countries. But the U.S. only exported 19,845 lb of potassium permangate to Colombia in 1988, all from the same manufacturer and all to well-established customers. Most or all of the chemical being used for cocaine production must be coming from somewhere else. Both SOCMA and CMA believe a lot of the material is coming from Europe and Asia as well, and that until these sources are as controlled as U.S. exports, those making illegal drugs will have little trouble getting the chemicals they need.

Regardless of the quantity of chemicals being diverted, the law says companies must report sales of them so DEA can be sure the products are going to legitimate users. In getting to this goal, a few administrative wrinkles remain to be ironed out. One of the things a company can do is to get its longstanding customers status as a regular customer. This will ensure that orders can be shipped promptly.

If it is dealing with a regular customer, a company has to notify DEA at least 15 days in advance of a shipment so the federal agency can check out the integrity of the receiving company. Ronald W. Buzzeo, deputy director of DEA's Office of Diversion Control, says his office has received 288 requests seeking regular-customer status for companies in Latin America. "So far, we have denied 35 of these as either gone out of business, or because of known involvement with drug traffickers or brokers," Buzzeo says.

Identifying regular customers is still causing some confusion, according to CMA's J. Garrity Baker. "In most transactions, where a company already has established a relationship with its customer, orders are taken over the phone," Baker says. "There is no proof of identity made each time." Baker is concerned that the DEA regulations could be interpreted as requiring proof of identity for each transaction. "A guy would have to come into the office and present identification each time," he says.

Susan Kernus, manager of government affairs at SOCMA, says her organization is worried about how easy it would be for DEA to tighten its controls under the law. "DEA can expand its list of regulated products, or it can further limit granting of regular-customer status. We are really going to have to keep our eyes open."

These and other problems are being worked out between the chemical industry and DEA. Baker says CMA has been meeting regularly with the drug agency to implement the law, but no changes have been made in DEA's original rules. "We've talked about possible resolutions of these issues," Baker says, "but DEA has just said it will take them under advisement and get back to us later."

Internationally, a little progress is being made. A convention has been worked out through the United Nations and signed by 77 countries, says DEA's Buzzeo. So far, only four countries, including the U.S., have ratified it. The treaty, if fully ratified, would set up an international monitoring system like the one being set up in the U.S., so all producers of these chemicals would be keeping track of how they are being used. And it will take such international coordination to stop the cocaine production. "If the U.S. were to stop exporting all the regulated chemicals tomorrow, the cocaine makers would just start importing them from other countries the next day," says Baker.

The chemical industry is confident it can work with DEA to curb the drug problem. It may just be a matter of the two entities getting to know each other better. Baker says it is significant that the only previous industry DEA has worked with is pharmaceuticals, which is much different. "The pharmaceutical industry has fewer manufacturers, fewer products, and sales are made in a highly regulated environment," says Baker. "Sometimes I think that DEA is trying to regulate the chemical industry the same way and it doesn't work."

In addition, Baker points out that DEA is a different kind of agency than other government offices monitoring chemical business. "DEA people are largely specialized cops, and this is the mind-set they bring to the job. They are not just administrators. We are seen as part of the problem in their eyes. If we would just stop selling the chemicals that are being diverted, the cocaine problem would decrease. So there is going to be a different relationship given these attitudes." □

Technician tests series of cleaners on a ceramic tile substrate at BASF's labs in Wyandotte, Mich.

Detergent Industry Ponders Products for New Decade

Bruce F. Greek, C&EN Houston

After a decade of developing and introducing new products and formulations, 1990 may be a year in which manufacturers take stock of what they have done and plan what they will be doing in the next 10 years.

Although few major changes are expected in the industry this year, some recent innovations in detergent products will be given extensive test marketing in the U.S. as well as in other parts of the world. If these innovations sell successfully, another round of rapid growth could begin for all of the soap and detergent industry and especially for individual parts of the industry.

Formulations that combine bleaching materials with cleaning materials and other components, for example, are among the products that will get close scrutiny this year. Other such products are detergents and fabric softeners sold in concentrated forms. These concentrated materials, so well accepted in Japan, now are becoming commercially significant in Western Europe.

Although outlooks point to a slowing economy, 1990 probably won't be a bad year for detergent makers and their suppliers. Yet, profitability could be held down as a result of a possible shift in consumer demand toward lower cost detergents in response to a slowing economy and inflation, and a possible failure in the marketplace of innovative products that cost a lot to develop.

Nonetheless, demand and production of detergents and component materials (especially surfactants) are expected to continue rising, with overall consumption growth about matching that of 1989 at 3 to 5%. Some components of detergents (enzymes, for example) likely will grow even more, although use of others, notably the phosphates used as builders, likely will continue to drop.

Lower cost of basic raw materials for making surfactants, other detergent components, and packaging likely will contribute to increased profitability for producers. Both detergent ingredients and packaging components make up the final product sold in the major detergent markets—household cleaners, institutional and industrial cleaners, and personal care products. Basic raw materials, however, are but a small part of the total cost of detergents. Producers of surfactants and plastic containers partially absorbed cost increases in 1988 and early 1989 when ethylene and other basic organic chemicals more than doubled in price. Just as some of those cost increases were passed on last year, some of the price declines may be passed on this year. Industry sources generally regard the impact of changes in basic materials prices as minor in the overall effect on profitability of either detergent ingredients or of products packaged for the consumer.

Consumer sentiment has become increasingly important to profitability. During the past decade, consumers have been willing to pay for better performance and convenience in detergents. More recently they have indicated a willingness to pay more for products that are less harmful to the environment. Yet, in past economic slowdowns, consumers have chosen less performance and convenience in order to pay less for their detergent. Whether consumers now will be slow to accept products more environmentally suitable if their real income declines is uncertain.

Consumers in general are expected to purchase more soaps and de-

Soaps and detergents at a glance

Soaps and detergents are formulated products designed to meet various cost and performance standards. The formulated products contain myriad components, such as surfactants to tie up unwanted materials, builders to improve surfactant processes and to remove calcium and magnesium ions, and bleaches to increase reflectance of visible light. They also contain various additives designed to remove stains (enzymes), prevent soil redeposition, regulate foam, reduce washing machine corrosion, brighten colors, give an agreeable odor, prevent caking, and help processing of the formulated detergent.

Sales: Estimated at about $11 billion in 1989, up from $10.5 billion in 1988. Expected to rise 3 to 5% in 1990

Production: Key detergent ingredients—surfactants—will total about 7.8 billion lb in 1990, up about 3% from 7.6 billion lb output in 1989

Producers: About 200 companies make components and finished products. Sizes range from tiny specialty manufacturers to major producers with detergent sales of over $1 billion. Chemical companies dominate the output of surfactants and components; formulators dominate final production and distribution

Manufacture: Numerous processing steps between basic materials for surfactants and other components that are used to improve performance and desirability. Ethylene, propylene, benzene, natural oils, ammonia, phosphate rock, trona, chlorine, peroxides, and silicates are among the various basic materials. Final formulation involves both mixing and chemical reactions

Prices: Average unit value for 58% of surfactant production (7.3 billion lb) sold in 1988 was 54 cents, up from 44 cents in 1987, according to U.S. International Trade Commission. Estimates of the prices of other components used in detergents aren't available

tergents this year than they did last year. In 1989, the value of product shipments reached $11 billion, up 4.4% from the total in 1988, or 2.5% in constant 1987 dollars, according to estimates of Leo R. McIntyre, chemical industry specialist in the Department of Commerce. This increase was less than half the 9.9% growth in 1988.

The value of surfactants shipped last year, however, increased about 14%—triple the rate for soap and detergents—to an estimated total of $3.65 billion. That growth was slightly higher than the 13% increase of 1988 over 1987.

The growth rate for all of the products containing surfactants and other ingredients used in soaps and detergents was 6.5% in 1989, to more than $37 billion. This group of products includes soap and other detergents, polishes and sanitation goods, surface-active agents, and toilet preparations.

Exports and imports account for relatively small portions of the soap and detergent industry. The Department of Commerce estimates that exports of soap and detergents in 1989 totaled $140 million, up about 4.5% from the previous year. Imports, at $86 million, increased 2.1% over 1988.

McIntyre forecasts that shipments of soap and detergents in 1990 will increase another 2.5% in constant dollars. Exports likely will increase 3.6%, and imports may rise a small amount. Liquid laundry detergents, a fast-growing segment of the detergents market, likely will post a 16% gain in shipments in 1990, to $1.8 billion. Shipments of liquid dishwashing detergents probably will grow even faster, 21% over 1989.

McIntyre predicts that in the longer term, shipments will continue to grow at an average of 2.5% per year in constant dollars through 1994. Heavy-duty liquid laundry detergents will exceed 40% of the market by 1994—compared with about 38% this year—spurred in part by increasing bans on use of phosphate builders in detergent formulations. Consumers frequently shift to liquid formulations in areas where phosphate materials are banned from detergents because they perceive that the liquid detergents give better performance than powdered detergents without phosphates.

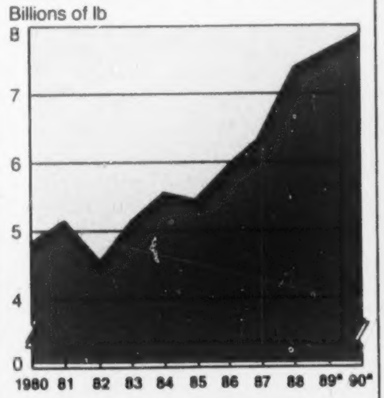
In other areas, McIntyre expects nonchlorine bleaches will eventually replace chlorine bleaches. Materials, such as the peroxygen bleaches, will get a boost when technology develops to activate them effectively at low wash-water temperatures, thereby extending their use to all laundering conditions.

In fuel markets, detergent formulations such as gasoline additives that limit buildup of deposits in automobile engines and fuel injectors likely will grow fast from a small base. McIntyre forecasts the value of such additives, including detergents, will grow 7% annually through 1994, when consumption will be worth about $150 million.

For surfactants, worldwide consumption will be about 15.5 billion lb this year, McIntyre estimates, with about half consumed in the U.S. Roughly one third of U.S. consumption goes to making detergents, with the remainder going into emulsifiers and wetting agents. Both exports and imports of surfactants increased strongly in 1989, reaching $290 million and $300 million, respectively. More growth is forecast for 1990, with exports and imports totaling about $350 million each.

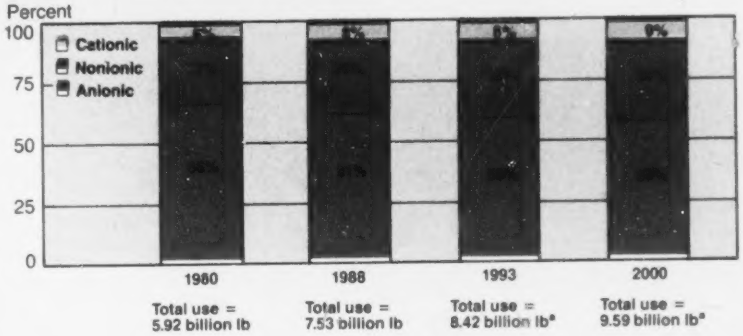
Longer term, the outlook for surfactants is for a growth in shipments of 3.8% annually in constant dollars through 1994. Prices for surfactants made using ethylene are expected to decline in 1990. A prof-

Organic surfactants output has risen since 1985

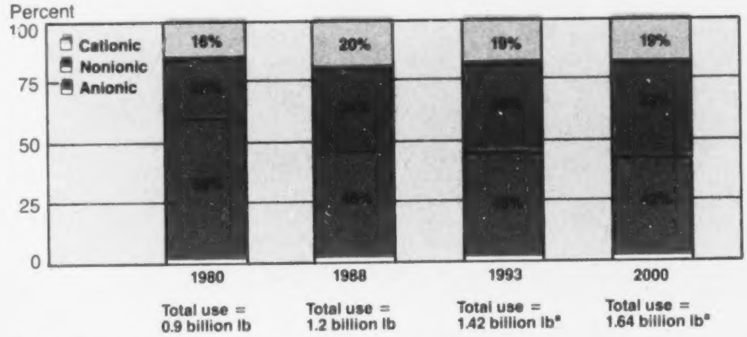


a Estimate. **Sources:** U.S. International Trade Commission, C&EN estimates

In all uses, cationic and nonionic surfactants grow faster than anionics . . .



. . . and faster in home laundry markets



a Estimate. **Source:** Freedonia Group

it squeeze could cause some of the smaller producers to cease output.

Surfactants are considered to be the key ingredient of soaps and detergents. Other components such as builders, bleaches, optical brighteners, enzymes, and fillers are needed to provide the cost and performance characteristics that make detergents acceptable in very competitive markets. Not all of these components go into every formulation. Some of the formulations sold to industrial markets, for instance, may contain only a single surfactant and a diluent. Such products are now considered rare because performance needs have led to complex formulations for products sold into the three major-use categories for formulated products.

Soap now has become a small part of the total output of surfactants. According to the U.S. International Trade Commission (USITC), surfactant production in 1988 was 7.3 billion lb. That total likely grew to 7.6 billion lb in 1989, and probably will increase further to 7.8 billion lb this year. Growth in surfactant output last year held in the 3 to 5% range, well below the sizeable growth of 17% in 1988; 1990 is expected to have similar growth. Output of surfactants has not declined since 1985, when it fell 2.8% as a result of a slump in industrial demand.

Of the more than 7.3 billion lb of surfactants produced in 1988, anionic forms, the active ingredient of which is a large carboxylate or alkyl sulfate radical, accounted for more than 60%. Running a distant second were nonionic forms, those that do not undergo electrolytic dissociation in water, accounting for 28% of the total. Cationic surfactants, where the working material is a cation, took 9.6% of the total, and the tiny group of amphoteric surfactants, compounds with both anionic and cationic properties in aqueous solutions, accounted for only 0.6% of total production.

Soaps, all anionic surfactants and alkali salts of carboxylic acids obtained from both natural and synthetic sources, made up more than 17% of total surfactant output. Sulfonates, salts of sulfonic acids largely made with alkyl benzenes and other aromatics, lignin, and other materials, were more than 31% of surfactant total. Various esters made by sulfating long-chain alcohols and ethers accounted for nearly 13% of the total surfactant output.

Among the various nonionic surfactants, various ethers (ethoxylated phenols and linear alcohols) were about 19% of total surfactant production. Carboxylic esters and amides, such as sorbitol-fatty acid esters and diethanolamine condensates, account for the remainder of nonionic output.

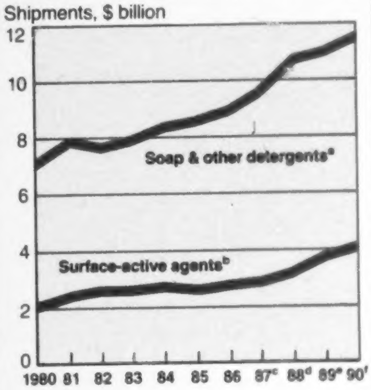
The near-term outlook for surfactant demand growth is a continued moderate annual average. Longer term, most sources expect growth to be lower than during the past five years. Whereas growth in the late 1980s averaged about 4% annually, growth in the first half of the 1990s may drop a third.

In a recent study of the U.S. surfactants industry, Freedonia Group, a Cleveland-based consulting firm, concludes that surfactants demand between 1988 and 1993 will grow 2.3% per year. By 1993, demand will total 8.5 billion lb of surfactants, worth about $4.6 billion, according to the study. During that six-year period, annual price increases will average 3.7%. By 2000, the demand will reach 9.68 billion lb, worth nearly $6.7 billion, Freedonia estimates.

This growth will result largely from consumption increasing faster than population, according to the study, continuing a long-established trend. In 1980, average demand per capita for surfactants was 26.2 lb, with total demand of more than 5.9 billion lb. By 1988, per capita consumption had increased to 30.9 lb and likely will increase to 33.1 lb in 1993 and to 36.0 lb in 2000. Population, meantime, is expected to grow 0.9% annually between 1988 and 1993.

Surfactants growth will be highest for use in products going to the household market. That market, however, will remain smaller than the industrial market, despite the

Value of cleansing agents shipments continues rising



a Standard Industrial Code 2841. b Standard Industrial Code 2843. c Preliminary. d Estimates by Department of Commerce. e Forecast by Department of Commerce. f C&EN estimates. **Sources:** Department of Commerce, C&EN estimates

faster growth. According to the Freedonia Group study, industrial uses in 1988 took almost 54% of the markets for surfactants, with household products taking slightly less than 30% and personal care products consuming the remainder. By the year 2000, industry uses of surfactants will rise slightly in market share, household uses will exceed 30% of the market, and the personal care products share will decline, the group says.

Two developments will largely account for the higher growth anticipated in the household demand sector of the surfactant markets. The first will be the greater concentrations of surfactants going into laundry detergents to meet cleaning requirements while washing at lower water temperatures. The second is that liquid detergents, which are generally higher in surfactant concentrations than powdered detergents, will continue to increase their market penetration during this decade, even though the major growth spurt is over.

The industrial market for surfactants will have average growth in most categories, according to Hans Kuenzel, a Freedonia research analyst. Special situations in the industrial sector involving personal contact and technical service lead to development of proprietary and highly specific surfactants. The industrial market contrasts with the household surfactant market in that it is highly fragmented, having a large number of small producers serving many customers. The household market, on the other hand, consists of a few manufacturers of detergents and cleaners supplied by a few large surfactant producers.

The industrial market covers a wide range of industries—including those that make petroleum products (including asphalt manufacture), agricultural and food products, coatings, textiles, and pulp and paper products. A large volume of various surfactants also is used in producing oil and gas, especially to enhance recovery.

Personal care product markets for surfactants will grow slowly because of a stagnation in soap demand. Liquid soap sales have plateaued, according to Kuenzel, and future growth depends on marketing emphasis and packaging innovations. Opportunities for growth in these markets are best in the nonirritating surfactants. Expanding demand for multifunctional products, such as shampoos and conditioners, will give better growth to this class of surfactants.

Many of the surfactants developed for household detergents eventually find use in formulations sold industrially or in personal care products. Because of efforts to maintain positions in the highly competitive household detergent and cleaner markets, much of the development work in surfactants is done in formulated detergents.

The procedure for developing new surfactants and other components of detergents has changed for many suppliers, as has the procedure for providing new materials for other industries. For instance, Du Pont now works from the markets back to products rather than finding markets for newly developed products. The aim now is to provide products and systems for using those products to meet strategic markets, says Phillip M. Richardson, market manager for Du Pont's cleaning products department.

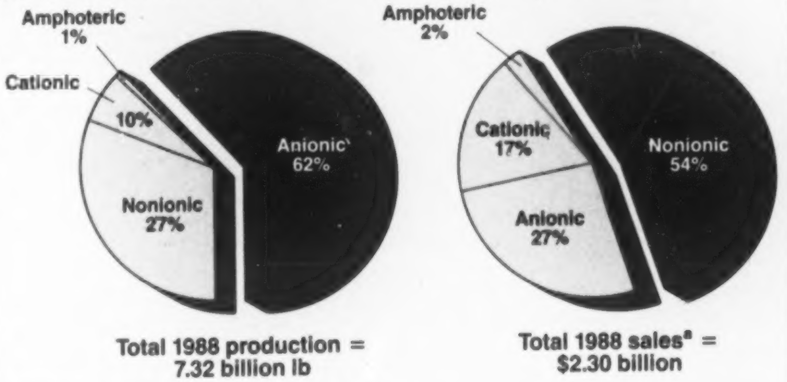
Basically, the marketing plan is directed toward helping customers and consumers meet their needs, Richardson says. The first step is to understand the needs and desires of consumers. Technology developed by Du Pont over many years then will be used (modified or fine-tuned as necessary) to change products to meet the users' needs. As the detergent formulations grow more complex, formulators will look more to suppliers for technical help in both distinct products and in systems to make the final products.

New surfactant development is but one of the challenges that face producers. New competitors with different motivations and feedstocks, worldwide competition and global marketing, growing environmental awareness, and increasingly complex formulations for detergents are some of the other challenges, says W. Jan B. Vogel, vice president for surfactants at Vista Chemical. Speaking to a joint American Oil Chemists Society-Chemical Specialties Manufacturers Association (AOCS-CSMA) conference on new horizons in the industry late last year, he noted that surfactants made from linear alkylates and alcohols that are subsequently sulfonated, sulfated, or ethoxylated, could be particularly affected.

Excluding soap, lignin derivatives, and the various cationic surfactants, derivatives of these intermediates (linear alkylates and linear alcohols) will be about 60% of the 3.5 billion lb of surfactants consumed annually in the U.S. and Canada. The other 40% includes many other surfactants, such as fatty acid esters, amides, alkylphenol ethyoxylates, the amphoterics, and block polymers of ethylene and propylene oxide. The linear alkylate and alcohol derivatives account for more than 90% of the surfactants used in the household products markets.

U.S. producers predominantly supplied the U.S. and Canada demand for alkylate and alcohol derivatives for surfactants in detergents until 1986, Vogel says. Now 5 to 10% of the demand is supplied by imports, largely from Western Europe and Third World nations. (Most new capacity to make these products has been built in the Third World or newly industrialized nations.) Overcapacity has now resulted partly because suppliers, particularly those in Western Europe that formerly exported to developing nations, lost

Anionics comprise almost two thirds of U.S. surfactant production while nonionics grab majority of sales



[a] Sales of 4.26 billion lb. **Source:** U.S. International Trade Commission

their export markets. Capacity beyond that needed to meet current domestic demand was built in Third World nations, adding supplies for export in competition with existing suppliers, further increasing overcapacity. The trend will continue because all but one of the plants planned or under construction are located outside the U.S., Western Europe, and Japan.

New capacity for making natural oil-based alcohols (made using coconut or palm kernel oil) also is coming, Vogel points out. Of more than 500 million lb announced new capacity for these natural alcohols, 400 million lb will be coming on stream within the next three years. Much of the current capacity of about 1.1 billion lb, for a while, will be sold in world markets. The result will be a shift in raw materials for alcohols used for making surfactants—from the current dominance of ethylene-based synthetic alcohols to about equal amounts of alcohols from ethylene and natural oils.

In the past, natural oil-based alcohols have had small impact on U.S. supply and price of surfactants. For the past 10 years, the cost of coconut oil (until now, the predominant source of natural alcohols for surfactants) has varied so widely that it has not established a sustained edge over ethylene-based alcohols. The less-than-competitive pricing of natural oil alcohols compared with ethylene-based alcohols may change, Vogel adds. Far more coconut oil has been available than palm kernel oil, the other major source of natural lauric oil. But, when the many new palm trees planted in the Western Pacific countries mature, Vogel expects that palm kernel oil output will jump to about 3.4 million tons in 2000, up from about 1.2 million tons in 1990. This output will be close to the expected coconut oil output of about 3.7 million tons. Two competing sources of lauric oil likely will stabilize prices, particularly since palm kernels are largely a by-product.

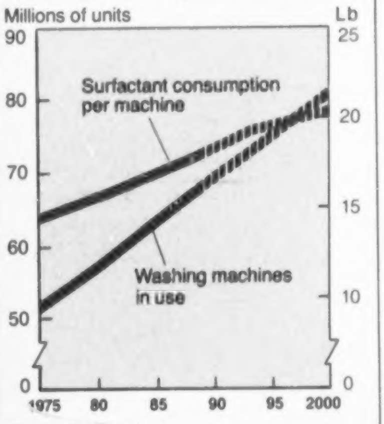
Production from the natural oil-based alcohol plant being built by Henkel in Cincinnati (with a capacity of 35,000 tons per year when completed in early 1992) partly will go to increase the production of a recently developed class of surfactants—the alkyl polyglycosides. About the same time that the alcohol plant will be completed, Henkel will start up a new 40 million lb-per-year plant at the same site, to make the glycoside surfactants, according to Gary W. Granzow, executive vice president of Henkel's APG™ surfactant group. Henkel made development quantities of these surfactants in a 2.5 million lb capacity unit at Crosby, Tex., in 1986 and expanded capacity to 10 million lb in 1988. After the new unit is on stream, the smaller unit will be moved to Cincinnati to be used in making various specialty glycoside surfactant products.

The glycoside surfactants technically are nonionics, Granzow says, but some show anionic characteristics. They have a variety of properties (depending on chemical composition) that allow them to be used in detergents for all three major markets. Some of the glycoside surfactants will tolerate a wide range of pH, from 3 to above 12, making them suitable for many industrial detergent formulations. Others are high foamers, suitable for shampoos in the personal care products market. For the larger volume uses, prices are expected to be competitive with the alcohol ether sulfates.

Another line of surfactants based on natural oils is expanding in the various detergent markets for use in combination with other materials. This is a class of alpha-sulfo methyl esters, often the laurate, developed by Stepan, a large producer of sulfonated derivatives for use as surfactants. The laurate derivatives as surfactants initially show most advantage for use in liquid household laundry detergents, says Edward H. Buening, senior business manager for industrial products. Others in this class are being developed for other markets.

The laurate ester can be combined with conventional soap and other components in making a formulated detergent with good cleaning properties, Joseph C. Drozd of Stepan told the AOCS-CSMA conference. The ester overcomes problems of using soap in hard water, difficulties from precipitation of calcium and magnesium soaps that

Use of machines outpace use of laundry surfactants



Source: Freedonia Group

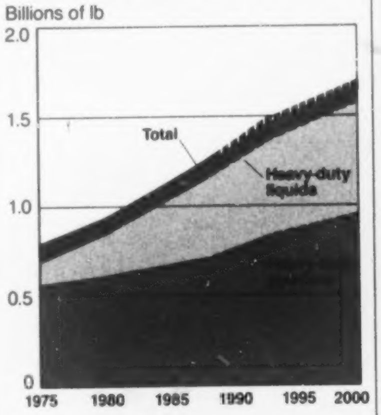
dull fabrics and surfaces, poor cleaning in cold water, and low solubility. Prior to this development, soap had experienced about a 50-year hiatus in its use in any home laundering detergents.

Soap in formulated detergents was largely replaced after World War II by alkylbenzene sulfonates. Branched chain alkyls were used first, and later linear chain alkyls. The linear alkylbenzene sulfonates (LAS) rose rapidly in demand and by 1970 accounted for a large share of surfactant consumption in household detergents. At that time, many other classes of surfactants began coming to the marketplace, limiting growth of LAS. LAS output languished in the 600 million to 700 million lb range for about 15 years, slowed partly by the price increases in benzene and kerosene (the source of the linear chain alkyls) as a result of the oil crises. As liquid heavy-duty laundry detergents gained wider acceptance, LAS began to grow again. In 1988, production of alkylbenzene sulfonates totaled more than 819 million lb, up 11% from production in 1987, according to USITC.

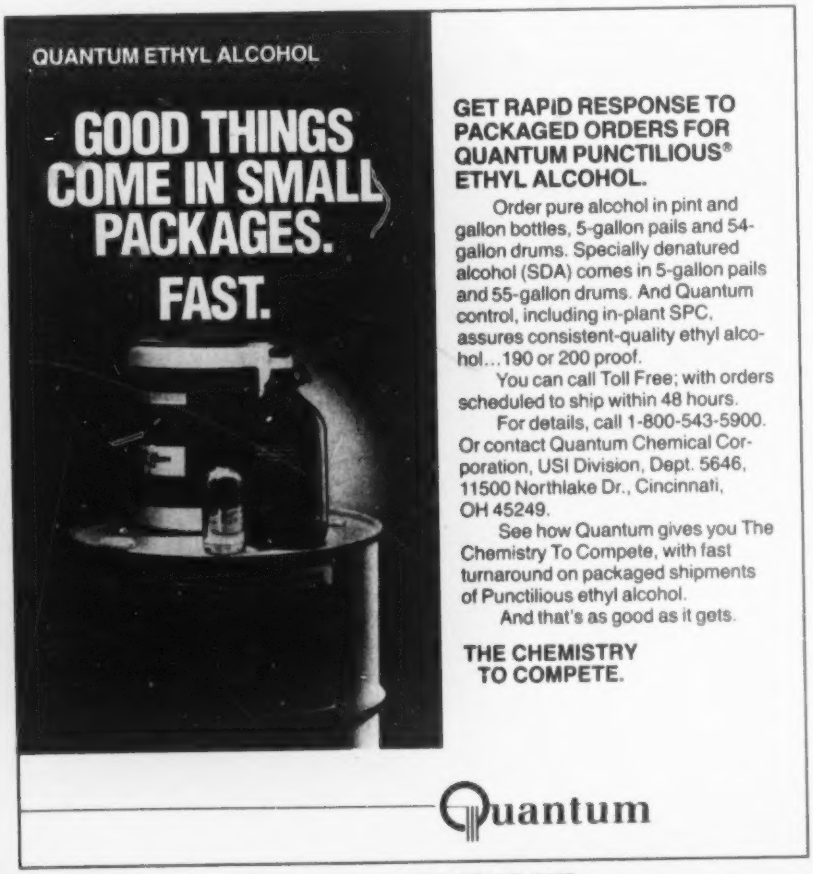
The growth spurt for LAS came on the heels of the higher costs of other surfactants based on ethylene, the cost of which rose rapidly during 1988, according to Cornelia A. Schirber, a business analyst for surfactants at Vista Chemical. Though temporary, the higher cost of surfactants such as alcohol ethoxylates (AE) changed the cost/performance factors involved in formulating detergents. Surfactants are selected for performance factors according to several factors including the type of detergent to be made, the cleaning performance expected of the detergent, and the detergent maker's own processing system and costs.

Most formulations now made combine various surfactants to get the desired performance, taking into account the influences of other components of the detergent such as builders or enzymes. By doing so, detergent producers can overcome differences in properties of individual surfactants. According to Schirber, important differences between LAS and AE are that LAS foams higher and more effectively cleans particulate soils and cotton fabrics, but is less effective on oily soils. And it is easier to spray dry (if making a powdered detergent) and more sensitive to water hardness.

Liquid detergent growth in home markets slows



Source: Freedonia Group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A shift to liquid detergents over the past five years has led to a substantial AE demand growth also because relatively few of these surfactants are used in powdered detergents, Schirber points out. But because liquid detergents contain about twice as much surfactant per wash load, the whole surfactant demand grew with the shift to more use of liquid detergents.

Despite these and other factors affecting surfactant demand, the respective costs of LAS and AE more often influence which is used in detergents. The competition between these two tends to stabilize prices, Schirber concludes. The competition in price, however, will be influenced in the future by the availability of increased supplies of natural oils that can be made into AE. However, the impact will be dampened by the cost of ethylene oxide, a synthetic material, used in making AE-containing alcohols from natural oils.

The outlook for AE and other

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Following addition of fragrances, milling converts soap to uniform flakes

alcohol-based surfactants remains good, according to Jerry G. Moffett Jr., business manager for detergent products at Shell Chemical. He forecasts a growth of at least 3% in demand for the alcohols in 1990, with possible higher increases owing to cost/performance factors. For instance, more use of enzymes in heavy-duty liquid household laundry detergents is raising demand for alcohol ether sulfate surfactants. The large decline in ethylene prices during the second half of 1989 is cited by Moffett and other industry sources as an aid to more use this year of surfactants based on synthetic alcohols.

Although raw material costs for synthetic alcohol surfactants are lower, the LAS surfactants will continue to grow at about the same rate, Vista Chemical's Vogel says. He notes that, beginning this year, no major reformulation away from LAS will occur and adds that this class of surfactant remains very cost-competitive.

Anthony J. Zoglio, business manager for surfactant intermediates at Monsanto, expects use of LAS materials for detergents to grow 3 to 4% this year, above the overall rise in demand for detergents that will be in the range of 1.5 to 2%. He cites increasing bans on the use of phosphate builders as helping demand for LAS. Use of liquid laundry detergents reaches 60% of detergent sales in areas of phosphate bans, well above the level of use in areas where phosphate builders are allowed in detergents. Because liquid detergents contain much higher concentrations of surfactants than powdered detergents, surfactant demand is boosted more than could be expected from detergent demand growth forecasts.

Changes in the use of builders resulting from environmental concerns have been pushing surfactant demand longer than the shift toward liquid detergents. Outright legal bans or consumer pressures on use of inorganic phosphates and other materials as builders generally have led formulators to raise the contents of surfactants in detergents. No clear measure of how important the bans are on increasing surfactant consumption compared with the shift toward liquid detergents has emerged, mainly because both actions are on-going.

But it does seem clear that, for this year and longer term, use of phosphates as builders in detergents for household use will decline. Builders, however, will continue to be an important component in formulated detergents because of their cost/performance characteristics. Builders in detergent formulations

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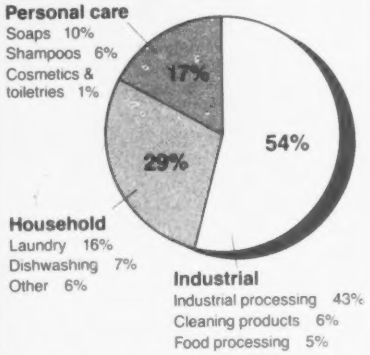
Industrial uses dominate surfactant demand



Total 1988 demand = 7.59 billion lb

Source: Freedonia Group

provide several functions, most important of which are to aid the detergency action and to tie up and remove calcium and magnesium from the wash water, dirt, and the fabric or other material being cleaned. Besides sodium and potassium phosphates, other builders that may be used in the various detergent formulations are citric acid and derivatives, zeolites, and other alkalis. For detergent manufacturing reasons, some builders are impractical for some uses. For example, citric acid causes caking in powdered detergents, making the free flow in filling lines difficult, yet it finds considerable use in liquid detergents.

Demand in 1990 for phosphate builders will be down about 3% overall, says Michael J. Berezo, business manager for builders/polyphosphates at Monsanto. Because of the expanding geographical area in which phosphate builders are expected to be banned, the use of phosphates in heavy-duty laundry detergents will be down about 5%. However, a slight increase in demand for these builders is expected for use in detergents going into the industrial and institutional markets and into automatic dishwashing detergents.

While agreeing with forecasts of flat growth to a modest overall decline in phosphate demand, Lewis G. Furman, marketing director of FMC's phosphorus chemicals division, expects a 1 to 2% increase in phosphate builders for the industrial and institutional and the dishwashing detergent markets. FMC also notes that new multifunctional household detergents containing bleaching materials and formulated with phosphates, continue to be introduced.

The company continues to oppose bans on use of phosphate builders because it does not believe there is conclusive evidence to indicate that bans result in improved water quality. Phosphates continue to offer the greatest performance benefit at the least cost to the consumer, FMC maintains. Comprehensive data are not as yet available on environmental acceptability of substitutes for phosphates.

In the field of industrial and institutional detergents, a shift from powdered to liquid formulations also has occurred, says Peter P. Carfagno, detergents products technology manager at FMC's research and development laboratories in Princeton, N.J. When it became clear how limited the concentrations could be in liquid products, a shift toward suspensions and slurry forms developed. These forms of detergents had to be metered and delivered to the cleaning site, leading to worker safety issues relating to the aggressive, often caustic-containing, formulations at the actual point of use. To overcome such potential problems, FMC developed formulations cast in pastes, gels, and block or other solid forms.

In some detergent formulations, larger and larger amounts of soda ash (sodium carbonate) are replacing inert ingredients, says William L. Breunig, marketing director in FMC's alkali chemicals division. An 18% increase in the use of soda ash during the past three years is attributed to its functionality as a builder, an agglomerating aid, a carrier for surfactants, and a source of alkalinity. Cost pressures on alternative materials also are involved. Cleaning compounds now annual-

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Numerous major producers supply large-volume surfactants

Surfactants	Producers
AMPHOTERICS	Alcolac, Du Pont, Henkel, Lonza, Miranol Chemical, Mona Industries, Sherex Chemical
ANIONICS	
Carboxylic acids and derivatives (largely based on natural oils)	Alcolac, Exxon Chemical Americas, Henkel, Lever Brothers, Procter & Gamble
Sulfonic acid derivatives (alkylbenzene sulfonates and other sulfonates)	Alcolac, Colgate-Palmolive, Desoto, Dow Chemical, Du Pont, Lever Brothers, Procter & Gamble, Stepan, Vista Chemical, Witco
Sulfuric acid esters and salts (largely sulfated alcohols and ethers)	Alcolac, Du Pont, Henkel, Lever Brothers, Lonza, Shell Chemical, Stepan, Vista Chemical, Witco
CATIONICS	
Amines and derivatives	Akzo, BASF, Du Pont, Enenco, Exxon Chemical Americas, GAF, PPG Industries, Procter & Gamble, Sherex Chemical, Witco
Quaternary ammonium salts	Alcolac, Akzo, Du Pont, Exxon Chemical Americas, PPG Industries, Sherex Chemical, Witco
NONIONICS	
Carboxylic acid amides and esters and derivatives	Alcolac, Ardmore Chemical, GAF, Henkel, ICI Americas, Lonza, PPG Industries, Quantum Chemical, Sherex Chemical, Stepan, Witco
Ethers (alkoxylated—especially ethoxylated—alcohols)	Alcolac, BASF, Du Pont, Exxon Chemical Americas, GAF, Henkel, ICI Americas, Monsanto, Olin, Procter & Gamble, PPG Industries, Quantum Chemical, Rohm & Haas, Sherex Chemical, Stepan, Texaco Chemical, Union Carbide, Witco

Source: U.S. International Trade Commission

ly consume more than 800,000 tons of soda ash, about 11% of the total U.S. market.

New and reformulated detergent products have created the need for more specific and unique characteristics in the soda ash product, according to Jeffrey J. Prickel, soda ash product manager for detergents in the same division of FMC. The company makes sodium carbonate by both the monohydrate and sesquicarbonate processes and is the only U.S. producer using the latter process, he adds. The sesquicarbonate process allows special grades of soda ash for various detergent industry requirements to be made, and results in better rates of hydration, flowability, high absorptivity and purity, and variable bulk density.

Incorporating bleaching agents into detergent formulations for home laundry has accelerated, as producers find test marketing results favorable and expand the availability of these "detergents with bleach" to national-scale. Such a multifunctional product can be sold successfully because of cost/performance considerations. Higher cost of such a product is justified by consumers because its performance allows users to curtail the need to store as well as add (as a second step) bleaching material.

Because U.S. home laundry uses shorter wash times and lower temperatures than European home laundry, chlorine bleaches (mainly sodium hypochlorite) have long dominated the bleach market in the U.S. Institutional and industrial laundry bleaching, where done, also has favored chlorine bleaches (often chlorinated isocyanurates) because of their rapid action. Growth in consumption of these bleaches in household markets has followed population growth for the past decade.

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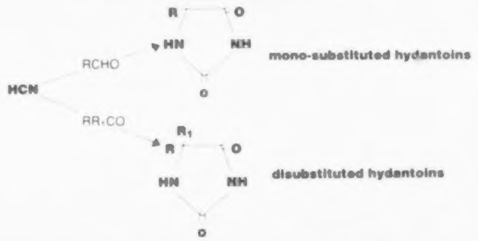

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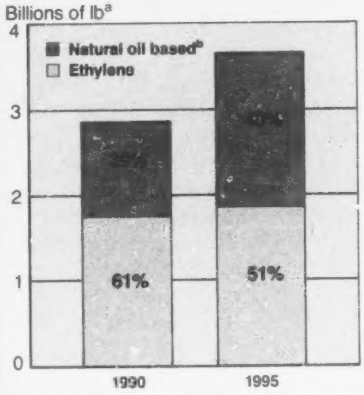
CIRCLE 20 ON READER SERVICE CARD

Natural oils to gain as surfactant alcohols source

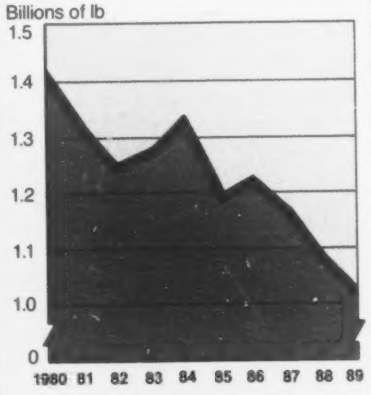


a Global surfactant alcohol capacity. b Coconut and palm kernel oils. **Source:** Vista Chemical

Other kinds of bleaching agents used in the detergent markets are largely sodium perborates and percarbonates, other than hydrogen peroxide itself. The perborates far exceed use of percarbonates in nonchlorine bleaches added separately to wash water or to a detergent formulation. The peroxygen bleaches are forecast to grow rapidly, for both environmental and technical reasons, according to various industry sources. Currently about 125,000 tons of the various peroxygens are consumed in detergent products, according to John Medina, director of peroxygens marketing at Degussa.

Regulatory pressures will drive the institutional and industrial market away from chlorine bleaches and toward the peroxygen bleaches, Medina says. The Clean Water Act amendments are requiring lower levels of trihalomethanes (products of reaction of organics and chlorine) in wastewater. Expensive systems may be needed to clean up effluents, or the industrial users of chlorine bleaches will have to pay higher and higher surcharges to municipalities for handling chlorine-containing wastewaters that are put into sewers.

Ban on STPP, TSPP as builders drops demand



Note: STPP is sodium tripolyphosphate; TSPP is tetrasodium pyrophosphate. **Source:** FMC Corp.

The shift toward liquid peroxygen bleaches has stabilized and is growing at about the rate of the gross national product, says Medina. The trend is toward solid peroxygens in a fully built detergent plus bleach that now is nationally available. Degussa is offering a sodium perborate monohydrate that the company says solubilizes easier and has a higher oxygen content that gives faster bleaching with the shorter wash cycles in the U.S. However, he adds that better activators are needed to give better bleaching at the short cycles combined with temperatures below about 60 °C.

The success of detergent-bleach combinations has spurred FMC to expand various research and development activities in such areas as systems to add peroxygens to cleaning applications where they have not been used before and to find alternative methods to add peroxygens to both powder and liquid detergent formulations, says Quentin Hopkins, industry manager at FMC's R&D department. None of this work has yet led to commercial products.

Current and expected changes in bleaching materials for various segments of the detergent industry are but part of what many industry sources call sweeping changes coming, due to environmental concerns and responses to efforts to improve the world environment. The so-called green movement that is seeking more environmentally acceptable products in Europe and Canada has gained enough momentum to be a factor to be dealt with in the U.S. in 1990, says Michael W. Buettner, marketing manager for BASF's performance chemicals.

Both detergent makers and their suppliers will devote greater efforts

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CIRCLE 33 ON READER SERVICE CARD

Machine operators use heavy-duty detergents for cleaning equipment

to develop more "environmentally friendly" products, he predicts. Preference will be given to such products by mass merchandisers, and manufacturers will be quick to respond, he adds. One example of attention to the trend in Europe is BASF's development of a new biodegradable stabilizer for perborate bleach, which is now being evaluated for use in detergents.

The existing detergent materials known to be environmentally safe and effective will continue to be widely used, industry sources agree. One example of such materials is LAS (and its precursor linear alkylbenzene), which Monsanto's Zoglio cites as being well tested and found nontoxic and environmentally safe. It will be difficult, however, to gain approval for new materials to be used in detergent formulations until their environmental performance is shown to meet current and new guidelines.

Environmental concerns are gaining attention in other ways. Disposing of the container that gets the detergent to the consumer often falls under concerns of handling plastic waste. One approach, begun on a test marketing scale in the U.S. in 1989 is a shift toward concentrated forms of detergents that require smaller containers.

The impact of the concentrates, whether for direct use or for dilution by the consumer, probably will be an increase in consumption of surfactants and other detergent components. On the basis of recommended use volume, no important change in surfactant and other component demand should be expected. But because consumers will have a tendency to overuse a concentrated form (which has happened with liquid detergent formulations), consumption likely will rise relatively.

Major developments in the detergent industry this year will be the growing demand for detergents with bleach as a component and more test marketing of concentrated forms of detergents. But much work on surfactant development and improvement of the many other currently used minor components will continue. Some of these developments will come to market this year, but likely will be barely noted, even by most in the industry. The developments will involve the components other than surfactants, builders, and bleaches. Work will continue on foam regulators, agents to resist soil redeposition, various optical brighteners, enzymes, fabric softeners, solubilizers, activators, and perfumes or other odorants.

All of these developments boost the effectiveness (including convenience) of formulated detergents in response to consumers' demands for even better cost/performance results. The improvements also are increasing the complexity of the formulations, especially those designed to have a high degree of multifunctionality. Despite the difficulties that arise from such complexity, development will go on. Producers of detergents and their components will again this year echo their statements that more new products have come out than ever before. ☐

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FEBRUARY 5, 1990

CHEMICAL & ENGINEERING

NEWS

PACIFIC BASIN

New age dawns for chemicals

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CHEMICAL & ENGINEERING
NEWS
FEBRUARY 5, 1990

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News of the Week

- **President Bush's proposed budget gives strong push to R&D including providing a 14% increase to the National Science Foundation plus more funds for big-ticket science programs.** Page 4

- **New class of compounds discovered by U.S., Belgian researchers may prove to be most potent AIDS-fighting drugs.** Page 5

- **Soviet Union to increase funding to its Academy of Sciences despite wide-ranging plans to cut spending, rein in deficit.** Page 6

- **Aristech Chemical accepts $27-per-share cash offer, worth about $877 million, from Mitsubishi/Aristech-management group.** Page 6

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Business

Patent rights will play a big role as biotechnology-based drugs move closer to commercialization. **Page 17**

Government

Asbestos removal projects are unnecessary, costly, and dangerous in many instances, says a recent study. **Page 21**

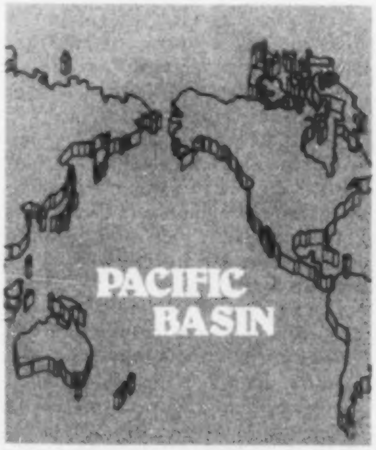
Clean air bills now in Congress receive contrasting reviews from various interest groups as to costs, benefits. **Page 23**

Science Policy

Switzerland's science and technology policy given a critical analysis both internally and by Paris-based Organization for Economic Cooperation & Development. **Page 24**

Science/Technology

Idea that carbon shells play a role in soot formation is sparking a debate among researchers in the field that is both professional and personal in nature. **Page 30**



News Focus

Pacific Basin, with its high level of opportunities for chemical development, provides focus for the new era of chemistry that is emerging, as global chemical industry responds to societal and marketing challenges. **Page 7**

Chemical & Engineering News

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LETTERS

CHEMICAL SAFETY

Potential hydroperoxide hazard

SIR: This letter calls attention to a potential hazard associated with the analysis of hydroperoxides.

In an analytical determination of hydroperoxide, one of the reagents is a saturated solution of sodium iodide in 2-propanol. An accident occurred when a technician, who intended to refill a bottle containing this reagent, chose a bottle of cumene hydroperoxide by mistake and poured about 700 mL of cumene hydroperoxide into 25 mL of sodium iodide in 2-propanol solution. The mixture decomposed violently, sending glass fragments throughout the lab area. Eye protection and lab coats prevented all but very minor injuries.

In subsequent testing, when 1 g of sodium iodide in 2-propanol was added to 30 g of 86% cumene hydroperoxide in a calorimeter at 26 °C, there was a rapid evolution of gas and heat (350 calories). Addition of 1 g of solid sodium iodide to 30 g of cumene hydroperoxide gave evolution of gas and 83 calories of heat. Addition of 2-propanol to the hydroperoxide gave little heat and no gas.

We believe these results show that small quantities of sodium iodide can catalyze a hazardous decomposition of cumene hydroperoxide at room temperature. The iodometric analytical procedure evidently avoids the gas-forming (catalytic) decomposition of the hydroperoxide by providing an excess of iodide (10 mL of sodium iodide in 2-propanol, about 13 milliequivalents of iodide); significant heat effects are avoided by restricting the sample size (not more than 2.5 milliequivalents of hydroperoxide or 190 mg of cumene hydroperoxide).

A. A. Duswalt, *Research Scientist*
H. E. Hood, *Research Associate*
Hercules Research Center
Wilmington, Del.

Effective use of databases

SIR: John Crum's analysis of the status of ACS finances (C&EN, Dec. 4, 1989, page 41) provides plenty of food for thought for all ACS members. I would like to point out one of the implications of the funding of ACS programs by other, self-sufficient ACS activities. I wrote in a letter to the editor (C&EN, Feb. 6, 1989, page 3) that users of chemical information were being harmed by the ACS policy of refusing to license certain *Chemical Abstracts* files, to commercial on-line vendors such as Orbit, Dialog, and Questel. The official ACS response at the time, as stated by Newman Bortnick, was that I was concerned only with convenience, and that there was little real damage to information users caused by the licensing policy.

Objections to that licensing policy continue to be strong in the information community, as reported to the ACS Council by Joseph A. Dixon, Bortnick's successor as chairman of the CAS committee (C&EN, Nov. 20, 1989, page 32). Dixon has also conceded that our objections to the licensing policy are based on a real concern about our ability to provide excellent service, and not on mere convenience. But he defended the need for the licensing policy in terms of CAS's need to maximize its income, because of the need of the income to subsidize important ACS programs.

At the open meeting of the CAS committee in Miami Beach, Dixon was asked whether it is right to use CAS as a cash cow to fund other ACS programs, at the expense of damaging the ability of information users to make the most efficient and effective use of CAS databases. I believe that the question is important enough to be brought before the entire membership of ACS. This ACS member believes that CAS databases should be made available to information users in formats and with database clusters that allow them to be used to maximum effect. If that has a negative effect on CAS income (still a debatable point), then let us find more appropriate means of funding those programs that are deemed desirable by the membership.

Stuart M. Kaback
Cranford, N.J.

Raise chemists' salaries

SIR: Dennis J. Sardella (C&EN, Nov. 20, 1989, page 3) was intrigued with the possibility of interpreting the decade-long decay of science enrollment in terms of socioeconomic factors. I would like to explore the problem, but minimize the socio slant. I prefer to view the problem and solution as economy and human nature. The solution could, but probably does not, require increased federal investment in education (C&EN, Nov. 20, 1989, page 5). Want more chemists? Raise chemists' salaries.

It is hypothesized that raising teachers' salaries will attract better teachers. Presumably, "better" teachers are recognized from a larger pool of candi-

Emerging Biotechnology Products Focus of Patent Disputes

Competing for markets and betting their survival on a few major products, biotech drug companies have lots at stake in patent rights battles

Ann M. Thayer,
C&EN Northeast News Bureau

Now that more and more genetically engineered drugs are close to becoming marketed products, patent rights will play a major part in determining which of the numerous biotechnology companies control major markets.

Currently, 45 companies have 80 products based on genetic engineering that are under development, according to the Pharmaceutical Manufacturers Association. Food & Drug Administration approval has been granted to only 10 biotechnology drugs, but about the same number of applications is pending.

The number of new major biotechnology products reaching the market is expected to rise throughout the 1990s. U.S. sales of human therapeutic and diagnostic biotechnology products will reach almost $1.3 billion in 1990, according to Consulting Resources Corp. of Lexington, Mass., growing to about $3.7 billion by 1995 and $9 billion by 2000. Despite the potential for large rewards, the costs for a biotechnology company are high—as much as $100 million per product and possibly even the fate of the company. The level of competition is also very high with at least two companies, if not many more, in each of the major product areas.

Cancer treatments account for the largest area of development, with 45 products, and include the interferons, interleukins, and monoclonal antibodies. Vaccines for hepatitis and AIDS (acquired immune deficiency syndrome) treatments are other major areas of R&D. Among the first drugs to be approved were interferon, human growth hormone, and insulin. The potential blockbusters, erythropoietin (EPO), which stimulates the production of red blood cells, and tissue plasminogen activator (TPA), a blood clot dissolving agent, have been approved in the past three years. Granulocyte colony stimulating factors (GCSF), which control the production and activity of white blood cells, and monoclonal antibodies, used to treat various cancers and septic shock, are on the horizon as some of the next big biotechnology drugs.

Although all the major areas of biotechnology drug development are seeing patent litigation, the trend in the industry is more toward cross-licensing than litigation, says David Webber, a biotechnology analyst with the firm of Alex. Brown & Sons in New York City. An important early example was the cross-licensing of the α-interferon patents between Schering-Plough and Hoffmann-La Roche, licensees of Biogen of Cambridge, Mass., and Genentech of South San Francisco. Not the panacea for cancer once expected, Webber believes the α-interferon market, already about $150 million worldwide, will continue to expand as clinical trials lead to other drug indications. γ-Interferon has recently been cross-licensed by Biogen and Genentech.

Similarly, the interleukins—used in cancer and immunotherapy treatments but not yet approved in the U.S.—have been cross-licensed. A patent dispute over interleukin-2 (IL-2) between Cetus of Emeryville, Calif., and Amgen of Thousand Oaks, Calif., was settled through a licensing agreement. A more important agreement, adds Webber, is that between Cetus and Hoffmann-La Roche, considered to be bigger players in the market.

Cetus led in drug patents based on biotechnology in 1988

	Biotechnology patents		
	Pharmaceuticals	Pharmaceuticals based on genetic engineering	Major drug development areas
Amgen	3	3[a]	Anemia, cancer, infection, hepatitis
Biogen	2	2	Cancer, AIDS, inflammation
Burroughs-Wellcome	3	0	Heart attack, cancer
Cetus	12[a]	6[a]	Cancer, AIDS, infection, diagnostics
Du Pont	3	1	Diagnostics
Genentech	11[a]	9[a]	Diabetes, cancer, AIDS, heart attack, human growth
Genetics Institute	5	4[a]	Anemia, hemophilia, cancer, infection, heart attack
Hoffmann-La Roche	5[a]	0	Human growth, cancer
Eli Lilly	11[a]	4[a]	Cancer, diabetes, diagnostics, heart attack, human growth
Ortho Pharmaceutical	6	4[a]	Anemia, transplants

[a] Among top 10 recipients of biotechnology patents in the U.S. in 1988. Source: Pharmaceutical Manufacturers Association

Hoffmann-La Roche was willing to negotiate, even sweetening the deal by taking a 3.5% stake in the biotechnology company and providing it with some needed capital. In the fiscal year ending June 30, 1989, Cetus reported losses of nearly $50 million, caused, in part, by spending for the launch of its IL-2 product. Since IL-2 will be Cetus' first major product, and FDA approval is expected this year, the firm could not afford the risk of being blocked from the market, he explains.

"It's possible for a company to be excluded from the marketplace, no matter how much good work it's done in the lab and clinic, if it doesn't have the right set of patent rights," says Webber. "It's often cheaper and more beneficial to try to settle a patent dispute out of court." Patent litigation is a two-edged sword, he adds, since one's own patent rights are put at risk when challenging another's.

The risk is considered fairly high since many unanswered questions surround biotechnology patents. For example, the U.S. Patent & Trademark Office, which has a backlog of thousands of patent applications, is just beginning to come to grips with granting patents in such a new and rapidly advancing technology. And the courts have yet to deal with issues on the scope and validity of patent claims. This is in contrast to the established pharmaceutical industry where both business practices and patent law are more mature. "With a lack of precedents, in terms of both case law and how the [biotechnology] industry will sort out such disputes," says Webber, "a cloud of uncertainty hangs over most of the products of these companies."

Companies would like to have guidelines as to what is patentable and how the courts will view biotechnology patents since the uncertainties affect their stock prices, business activities, and the outlook of investors. "It's probably a little early to try to extract any trends," says William S. Feiler, a patent attorney with the firm of Morgan & Finnegan in New York City. "I suspect that we are going to see the pace [of litigation] pick up when people get a better feel for how the courts are going to react on certain issues or how they will interpret claims." At least a dozen significant cases are pending, but very few decisions have come out.

Prior publication dooms patent application

In an area with few precedents, the U.S. Court of Appeals for the Federal Circuit has established an important one on the conditions for obviousness in biotechnology inventions. An invention is patentable if it differs from any description in the prior art, such as other patents or publications, available more than a year before an application is filed. The court's August 1988 decision, *In re O'Farrell*, made clear that inventors will not be protected against the apparent obviousness of their invention, even if the prior art is their own scientific publication.

In 1978, the University of California filed for a patent on a method of producing a predetermined protein in genetically engineered bacteria, based on work by Patrick H. O'Farrell, Barry A. Polisky, and David H. Gelfand. The patent application was rejected in 1981 as being obvious, based on a 1976 paper by Polisky, Robert J. Bishop, and Gelfand describing a method for the expression of frog ribosomal RNA in genetically engineered bacteria. The university also became involved in a dispute over a competing patent application filed in 1977 by the biotechnology company, Genentech. Genentech received a broad patent on recombinant proteins in 1987. After appealing the rejection of the patent, the case went to the court of appeals.

Although the O'Farrell patent claims were very similar to the method described in the 1976 paper, the inventors argued that there were important differences. Based on existing precedents, an invention still may be patentable even if it is "obvious to try." If there is not a reasonable expectation of success, or undue experimentation is required, or the technology is so new that the prior art gives only general guidelines, it may be considered not obvious. Since proteins had not been produced successfully by recombinant techniques, it was argued that success with a gene encoding for a protein, rather than RNA, was not certain. However, the court ruled that the prior art explicitly suggested the method and substitutions made between it and the claimed invention.

"It is hard to escape from thinking that the court adopted a strict construction of the [published] article because it had been authored by two of the three inventors of the patent application under review," comments Peter Ludwig, a patent attorney with the firm of Darby & Darby in New York City. In referring to it as the case of "publish and perish," he stresses the need to balance the "opposing forces of publication and patenting," in protecting university-based inventions. It was a "judicial anomaly," he says, that the appeals court also chose to comment on the patent of an unrelated party in its decision. Opinions differ as to whether the court's comments, suggesting that the Genentech patent followed on the work done by O'Farrell et al., might be used in challenges of the broad Genentech patent.

On a case-by-case basis, there have been some important precedents, says Feiler, but only one U.S. case involving genetic engineering has been fully litigated. Hybritech, now a subsidiary of Eli Lilly, sued Monoclonal Antibodies, a Mountain View, Calif.-based biotechnology company, alleging that Monoclonal Antibodies' immunoassay kit infringed Hybritech's patent. In 1985, the U.S. District Court in San Francisco ruled that Hybritech's patent was invalid since the invention claimed would have been obvious to a person of ordinary skill in the field at the time the invention was made.

The patent was upheld by the U.S. Court of Appeals for the Federal Circuit, the highest court, other than the U.S. Supreme Court, to hear patent cases. Explains Peter Ludwig, an attorney with the firm of Darby & Darby in New York City, obviousness is measured against four criteria. These are the scope and content of any prior art; the differences between the prior art and the claimed invention; the level of skill in the art of the invention; and any evidence of secondary considerations such as commercial success, unexpected results, or long-term need. Although the Hybritech case was uniquely decided on the fourth criterion, questions as to how the three remaining tests for obviousness will be applied to biotechnology inventions continue to be significant issues in patent cases, says Ludwig.

In an initial stage of a case between Genetics Institute, Cambridge, Mass., and Amgen, one of the first decisions relating to the issues of validity, infringement, and enforceability of two patents was made. The two companies are battling over rights to EPO. In its first year, sales of EPO are expected to be more than $100 million and, if approved for treatment of anemia in cancer and AIDS patients in addition to those with kidney failure, the market could reach $300 million. Amgen received FDA approval for its EPO in June 1989; Genetics Institute has not received approval, but has been expected to for some time.

Certain claims of both companies' patents were upheld and found to be infringed by the other party, says Feiler. However, Genetics Institute's licensee, Chugai Pharmaceutical of Tokyo, was not found to infringe the Amgen patent. Amgen's patent covers the gene sequence, vectors, and transformed host cells—intermediates in the product of recombinant EPO. Genetics Institute's patent covers purified EPO.

"It's an important precedent that the pure protein claim will cover a recombinant product," says Feiler. The decision by the court was not completely unexpected. In a case between Genentech and Scripps Clinic & Research Foundation involving Factor VIII, the blood clotting agent used to treat hemophilia, the Scripps patent on the purified protein was upheld initially. The case is on appeal. That a patent on a purified natural protein covers all forms of the protein, whether produced by recombinant or other means, is expected to have significant ramifications for the biotechnology industry.

An example is the situation now faced by Amgen and Genetics Institute. "In a strategic sense, Genetics Institute came up the winner in this round," says Webber. Genetics Institute is trying to block Amgen from marketing EPO in the U.S., but Amgen cannot block Genetics Institute and its licensee from importing EPO made in Japan. However, the case is not yet completely over.

"The question for Amgen at this point, having really lost the first important round, is whether it should reach an agreement with the other party," he points out. Process patent applications filed by the two companies for production of EPO are being held up in interference proceedings at the patent office. If Amgen were to get a process patent, it is possible that it could block Chugai from importing materials made in a foreign country with a process covered by a U.S. patent, resulting in a standoff between the companies.

There are incentives for both parties to settle. "Amgen has had a high operating budget this year in order to prepare for the launch of its product," Webber says, "and can hardly afford the interruption in EPO revenue flow." Amgen reported a net loss of slightly more than $8 million for the fiscal year ending March 31, 1989, on revenues of more than $67 million. Genetics Institute, which reported a loss of nearly $29 million for the year ending Nov. 31, 1989, would like to begin manufacturing in the U.S. rather then only receiving royalties on U.S. sales of its EPO by its licensee.

With 1989 revenues of more than $400 million, and two major products on the market, Genentech can afford to defend aggressively its patent positions. "The cost of litigation is high, especially for a small company," says Stephen Raines, Genentech vice president for intellectual property, "but compared to the cost of development, it's a very inexpensive route if you are successful." Litigation may cost a few million dollars for the rights to products worth hundreds of millions. The company's two major products, human growth hormone and TPA, had 1989 sales of about $123 million and $196 million, respectively.

Soon after receiving its patents on human growth hormone, the company became involved in infringement suits with Eli Lilly and Hormone Research. In August 1988, the Federal District Court in San Francisco found that Genentech did not infringe the patent held by Hormone Research and its licensee, Hoffmann-La Roche. The case is currently pending on appeal, as is one between Genentech and Lilly. As an alternative to litigation, Hoffmann-La Roche and Lilly signed a cross-licensing agreement on human growth hormone in 1987. For similar reasons, Genentech and Genetics Institute have decided to cross-license Factor VIII with their respective licensees, Miles Laboratories and Baxter Healthcare.

Genentech has had some setbacks. It lost its patent rights to TPA in England in an appeal of a dispute with Wellcome (C&EN, July 13, 1987, page 5). And some initial judgments in U.S. cases have not gone entirely smoothly for the company. "It's worth the gamble," believes Raines, with questions surrounding biotechnology patents so unsettled. "The only thing you generate for all your work and investment is patents," he stresses, "and if you don't assert them, it's almost the same as if you didn't have them." To become a major pharmaceutical company, he explains, a small company must have market exclusivity. Genentech has been, or currently is, involved in suits with several companies over TPA.

However, TPA has not turned out to be the blockbuster drug once expected. Before FDA approval for Genentech's TPA in late 1987, the market was estimated at nearly $250 million for its first year and close to $1 billion now, says Webber. The market and competition from other products, which many believed would drop out with the appearance of TPA, was seriously misjudged. Second-generation TPA and new drugs are starting to emerge.

Expanding markets for the approved drugs and several new multimillion-dollar markets are expected in the 1990s. But the biotechnology industry will still be left with questions surrounding its major patents. "It's going to take time for the whole system to adjust," says Raines. "We're not happy living in this era; we'd like to see the law get settled." □

Switzerland's Science, Technology Policy Undergoes Critical Analysis

OECD review of Alps nation's research efforts dovetails with recent Swiss examination of the aims and institutions of country's R&D policy

Dermot A. O'Sullivan, C&EN London

The general perception of Switzerland is that of a country in which science and technology combine to play a key role in national life. This is exemplified in many areas of endeavor, from the world-renowned precision of Swiss watches to the sophisticated pharmaceuticals and chemicals developed in the country.

For science and technology to flourish, spending on research and development must be maintained at a fairly high level. Much, too, depends on the conditions in which the R&D effort is conducted and maintained, and the underlying policies at the national level that foster scientific advances. These and related issues are the subject of a detailed review of Switzerland's national science and technology effort undertaken by the Paris-based Organization for Economic Cooperation & Development.

Although the review serves to confirm the importance attributed to the research and development effort by the Swiss, it does pinpoint areas of the system that could be improved. One suggestion stems from the need for more scientists and engineers. Another derives from the spirit of independence that the 26 cantons, or states, seek to maintain in the face of planning by the federal authorities in Bern. Also, there is a recognition of weakness in fostering growth in some of the newer areas of scientific endeavor, such as information technology and genetic engineering.

The OECD analysis appears at a time when the Swiss themselves are going through an across-the-board examination of their science and technology effort. This examination is directed toward reshaping the aims and institutions of the country's research policy. As Flavio Cotti, head of Switzerland's Federal Department of Home Affairs, points out, ways to strengthen cooperation between universities and industry is a primary concern of the country's Council of Ministers. No less important is the continuing assessment of research, and of measures that need to be taken to encourage it.

Switzerland's gross domestic spending on R&D in 1986 (the most recent year cited in the OECD study) came to just short of $2.87 billion, nearly 2.9% of the country's gross domestic product (GDP). Industry accounted for 79% of the total, public funding 21%. "This makes Switzerland the OECD member country with the highest business enterprise participation in the funding and implementation of R&D, and with the lowest public sector involvement," the OECD report notes.

The number of people engaged full time in R&D throughout the country in 1986 amounted to 45,000, some 12% of whom are women. Of the total, 35,000 were associated with business enterprises, 7100 were involved in higher education, and 2900 worked in one of the branches of the federal government.

Set against GDP, Switzerland is among the most highly R&D intensive of the 24 OECD member countries. In fact, the 2.9% of GDP spent in 1986 likely is an underestimate because it doesn't take into account the R&D expenditure from a number of sources. Not included, for example, is the direct funding of R&D activities by cantons and communes over and above their contributions to the general universities fund, or the R&D activities of the country's federal institutes of technology in Lausanne and Zurich. Neither do the figures reflect contributions from private, nonprofit bodies, R&D undertaken by the service sector, nor funding that comes from outside the country.

Chemicals high in R&D spending as percent of sales

$ Millions (1986)	Sales	R&D spending as % of sales
Chemicals	$6553	27%
Electrical engineering	4830	16
Machinery & metallurgy	7756	7
Research labs	216	28
Others[a]	8742	2
TOTAL	$28,097	12%

[a] Other sectors are construction, food products, paper and textiles and clothing, and watchmaking.
Source: Swiss Union for Commerce & Industry

The data cited in the review, drawn largely from information supplied by the Swiss Union for Commerce & Industry, point to some interesting facts. By far the highest amount of R&D spending was made by the Swiss chemical industry. The $1.75 billion or so represented more than 50% of the $3.26 billion invested by the 10 industry groups analyzed. Of the chemical industry's total, 51% was spent in Switzerland.

The chemical industry's spending on R&D in relation to its total sales also was one of the highest of the industry groups. The $1.75 billion represents nearly 27% of the $6.55 billion in chemical sales.

The relative intensity of R&D activity by the chemical industry is further highlighted by the fact that the 109 companies that make up the group are only a quarter of the number that make up the machinery and metallurgy group, the largest in terms of the number of companies and the number of employees. Moreover, chemical firms account for less than 10% of the 1157 enterprises in all of the 10 industry groups studied. Nevertheless, the 9300 staff members engaged full-time on chemical R&D exceed 14% of the chemical industry work force, in contrast to 6% in the case of the machinery and metallurgy industry, which employs twice the number of workers.

The electrical engineering industry is next in importance in terms of R&D funding, although well below chemicals. The $784 million spent, 16% of the electrical industry's sales, represented 24% of the 10 industry groups' total.

The OECD study draws attention not only to the substantial amount (38% of the 1986 total) of R&D undertaken outside Switzerland, "but also to the fact that expenditure on R&D abroad is growing more rapidly than domestic expenditure. This probably reflects a deliberate international attitude as much as a relative scarcity of scientific and technical personnel in Switzerland."

A coordinated national science policy for Switzerland got under way in earnest in the 1960s. Since then, various bodies have emerged to foster its implementation. The Swiss Council of Science, an advisory body to the federal government, was created in 1965. It sets out the basis of national science and research policy, and proposes measures for its implementation. One permanent working party deals with university policy, another with research policy.

Switzerland's Research Act, which came into force in 1984, provides a legal framework for various research stimulation measures. These include subsidies for research centers in such specialized fields as electronics and microtechnology, encouragement of ancillary scientific services like technical information and documentation, and Swiss participation in a number of international scientific organizations and collaboration in various international research programs. Within the act, coordination of research is the primary responsibility of the research bodies.

The most prominent of these is the Swiss National Science Foundation. Established in 1952, it serves as the country's main research promotion agency. The bulk of SNSF's funds goes toward supporting research at Switzerland's seven universities and its institutes of higher learning in Lausanne, St. Gall, and Zurich. Some of the money is used to help young scientists study outside the country. The foundation's current 1988 through 1991 program, funded at about $400 million, puts special emphasis on environmental studies and on emerging engineering technologies. The program is the first formulation of a coherent approach to research support by the national government.

SNSF also participates in selecting topics for Switzerland's national research programs in special applied research areas of social importance, and is responsible for implementing the programs. Work now under way within the national research program plan includes research in microelectronics and optoelectronics, applications of artificial intelligence and robotics, and studies on biomedical techniques and new materials.

The Swiss Council of Science has set up a permanent body to conduct what's referred to as an advance warning in research policy. By monitoring developments in science, the economy, and society at large, the federal government is provided with specialized assessments of the opportunities and risks associated with various developments. These assessments are available to all of the country's science bodies and to the general public.

The OECD study cites three areas of influence on Swiss science and technology policy. One is the distribution of function between state and private industry. Funding for education and basic research comes largely from government but industry picks up most of the tab for applied R&D.

Now there is a tendency for these lines of demarcation to blur somewhat. Closer ties are being forged between educational and research establishments and industry, and more public funding is finding its way to industry-related R&D. "The main reason for this is the acceleration of technological development,

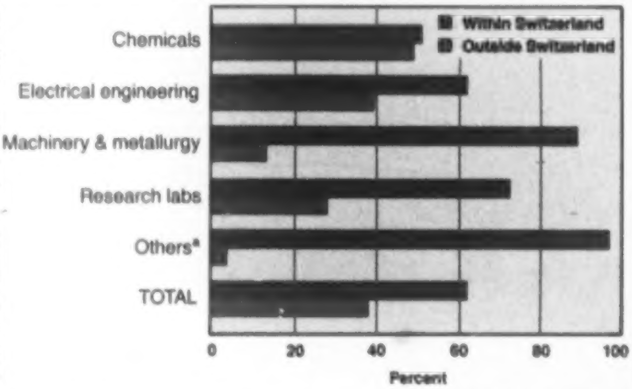
Chemical sector spends most on R&D . . .

$ Millions, 1986	R&D spending	% of total	Within Switzerland	% of total	Outside Switzerland	% of total
Chemicals	$1753	54%	$897	45%	$856	69%
Electrical engineering	784	24	481	24	303	24
Machinery & metallurgy	522	16	455	23	67	5
Research labs	61	2	44	2	17	1
Others[a]	138	4	132	6	6	1
TOTAL	**$3258**	**100%**	**$2009**	**100%**	**$1249**	**100%**

[a] Other sectors are construction, food products, paper and plastics, technical services, textiles and clothing, and watchmaking.

Source: Swiss Union for Commerce & Industry

. . . and a large amount of it is spent abroad



which is causing problems for small and medium-size firms in particular, and the very large subsidies given by governments to research and technology in countries in competition with Switzerland," OECD notes.

Another area centers on the autonomy of the Swiss universities and state influence on the direction of research undertaken by them. The federal government fixes the long-term objectives of research policy and can impose these objectives directly, a factor that must be kept in mind by grant recipients. "Coordination of research, on the other hand, is to a large extent based on the principle of voluntary cooperation among the bodies concerned, a principle to which exceptions are rare," the study adds.

The third area cited in the OECD review stems from the idea of federalism in Switzerland. The cantons are primarily responsible for education policy. The federal government can curtail their powers only in specific circumstances. This has consequences for the unity of the education and research system and for research conducted at the universities, although the federal government's subsidization of higher education and research provides it with some influence.

"These three areas have strongly marked the development of federal science policy in Switzerland, and have occasioned some setbacks," the OECD review points out. "There has, however, been continuing progress in recent years, and the encouragement of research by the federal government has attained a respectable level. On the other hand, there does not yet exist in Switzerland a government technology policy for reasons inherent in the distribution of functions between the state and the private sector.

"Nevertheless, there appears to be the beginning of a technology policy resulting from the encouragement given to applied research, and from a growing awareness of the implications for technology policy of other government activities. The technology policy debate is likely to become increasingly important in Switzerland over the next few years." ☐

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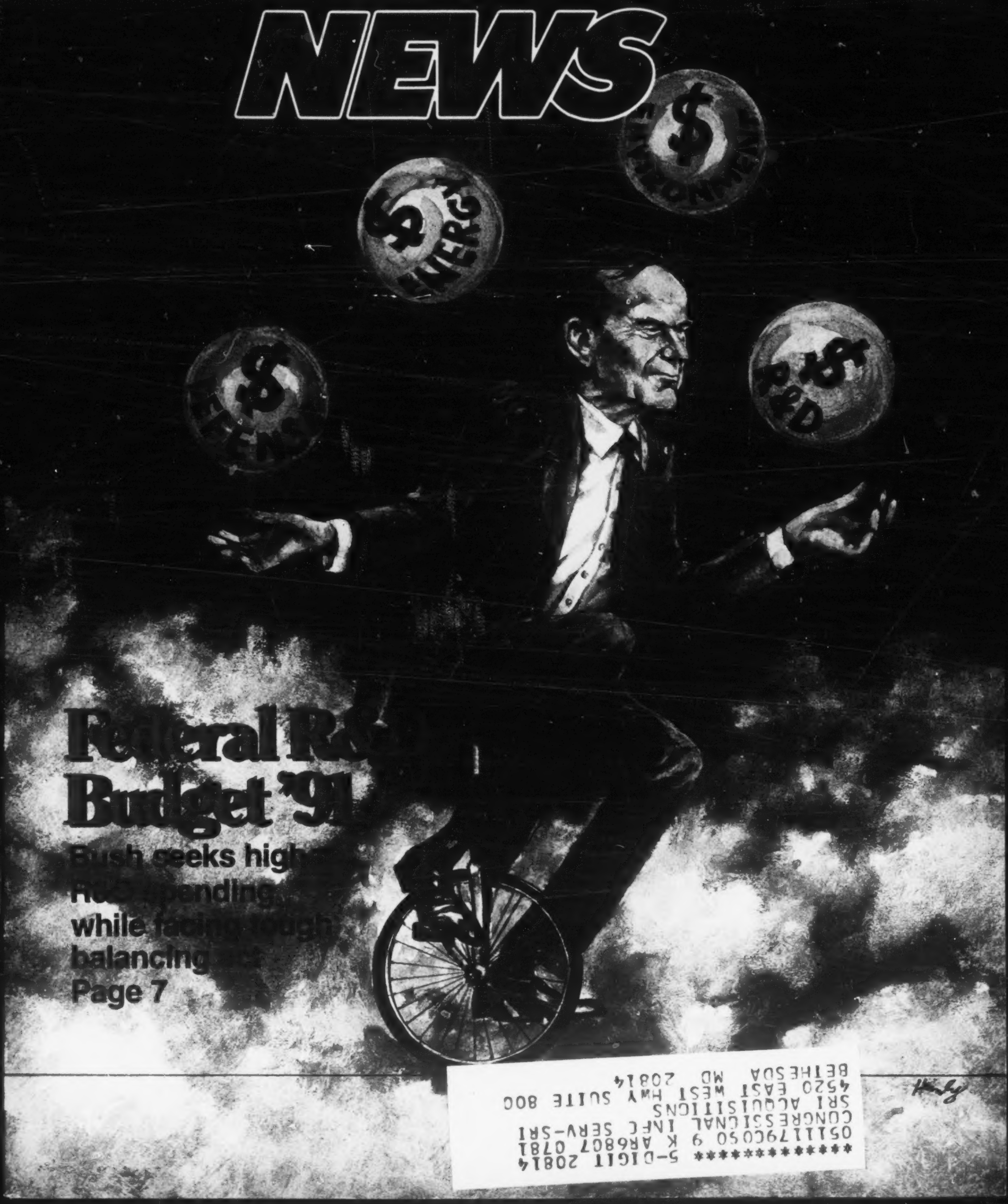
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Federal R&
Budget '91

Bush seeks high
R&D spending
while facing tough
balancing act
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News of the Week

- **Funding and policy conflicts over big science projects were the focus as White House science adviser testified at House "science posture" hearing.** Page 4
- **New type of gaseous fuel cell that operates at room temperature may provide low-cost source of emergency power.** Page 5
- **At Senate hearing, chemical industry disputes charges that chemicals are being diverted from U.S. firms for production of illegal drugs in Latin America.** Page 5
- **President Bush retains low-key stance on global warming in addressing an international meeting on global climate change held last week in Washington, D.C.** Page 6
- **Roche Holding Ltd., the Swiss chemicals and pharmaceuticals producer, is buying a 60% interest in Genentech.** Page 6

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Business

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Recommendations for better assessing, communicating risks related to pesticide residues are outgrowth of recent pesticide conference. **Page 18**

Uncertainty analysis needs to be incorporated in risk assessments and in risk management decisions, according to policy analyst's report. **Page 20**

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Elena Ceaușescu's apparently fraudulent scientific career is attested to in anecdotal evidence from Romanian and other scientists. **Page 21**

Science/Technology

Cubical singlet diradical 1,4-cubadiyl is proposed by three groups as structure of reaction intermediary 1,4-dehydrocubane. **Page 24**

Process converts discarded polyethylene terephthalate bottles to thermal insulation foam. **Page 25**

Books

"Blacks, Science, and American Education" relates contributions of early black scientists, assesses current science education of blacks. **Page 28**

News Focus

President Bush's proposed 7% increase in 1991 R&D funding seems healthy compared with total federal budget, yet most of total R&D increase is targeted for various "big-ticket" science projects. **Page 7**

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LETTERS

CHEMICAL SAFETY

9,9-dichlorofluorene

SIR: Two of our students recently synthesized 9,9-dichlorofluorene. Neither the paper describing the synthesis they used [Ray, F. E., Albertson, C. E., *J. Am. Chem. Soc.*, **70**, 1954 (1948)] nor the original synthesis [Smedley, I., *J. Chem. Soc.*, **87**, 1249 (1905)] made mention of any sensitivity from this compound.

One of our students subsequently spilled a solution of the 9,9-dichlorofluorene in hot glacial acetic acid on her hand. A rash soon developed locally and subsided, but within a week reappeared as a severe case of dermatitis, which spread to both arms, legs, and her face, with accompanying itching and swelling. A literature search revealed a similar reaction to 9,9-dibromofluorene [Sampey, King, Roe, Childress, *Science*, **621** (1947); Sampey, Childress, *J. Am. Chem. Soc.*, **70**, 1979 (1948)]. For our student, even with treatment with Benadryl and steroids, the dematitis was severe for a week and slowly subsided over the next few weeks. We caution others about working with this compound.

Terry L. Newirth
Associate Professor
Haverford College

Editor's note: The Chemical Manufacturers Association and other authorities recommend immediate flushing with cold running water for at least 15 minutes following chemical contact with human skin.

Photography's roots

SIR: Congratulations on providing what is probably the best short-form 20th century survey of the technologies of the launch of photography to your readers (C&EN, Dec. 18, 1989, page 26). John L. Ennis is to be commended for the mix of chemistry and sociology, which keeps the years and breakthroughs so firmly separated.

But a few adjustments will be of equal interest. The ambrotype, immediate major successor to the daguerreotype, did not capture the market because of public demand for portraits in the daguerreotype mode. Photographers gratefully rushed to ambrotypy, a simpler process without need for the costly silver-plated copper; with an image visible from any direction in any light; and broadening the market with a lower cost per image. It was made on the glass previously stocked as cover panels for the fragile daguerrean image.

The photographers used existing camera cases and all of the existing leather cases necessary to protect glass covering the daguerrean images. It was a speedy transition from a complicated procedure to a safer (no mercury), lower priced system. On-paper photography displaced the on-glass images within a few years.

The tintype (ferrotype, melainotype) was patented (not invented) by Hamilton Smith and his student Peter Neff, whose farmer-father financed the effort. It was invented in 1853 in France by chemist Adolph Alexandre Martin (1824–96) and was patented there in the same year as the U.S. patent (1856). Earlier, in 1853, the process was used by Giles Langdell of Philadelphia to make images on black paper (melanographs, atrographs).

The tintype succeeded because it made possible the penny picture (12 for 10 cents) at the time of the Civil War. The public saw the first image of Abraham Lincoln on the 5-cent campaign button of the election that made him president. The patents were not enforceable. Neff left photography.

Finally, Daguerre did not make his camera (your caption on page 35). The equipment came from the optical shop of his camera obscura supplier, Chevalier of Paris; after June 1839, the body and necessary fuming boxes came from cabinetmaker Alphonse Giroux, a relative of Daguerre's wife. Giroux also made the cameras that he and Daguerre then sold following demand created by the government's August 1839 announcement.

Interest in photography's roots during 1989 led to your essay among others in the popular press and also to found-

Corrections

- Dec. 18, 1989, page 16: The new composites encyclopedia is entirely the product of VCH Verlagsgesellschaft's American subsidiary VCH Publishers, New York City.
- Oct. 16, 1989, page 61: The blood cells termed polymorphonuclear leukocytes are, instead, macrophages.
- Jan. 15, page 28: The studies of synthetic diamond films were made by Teruo Yagishita of Fujitsu Laboratories, not Teruo Yagashita.

President Proposes 7% Increase in Federal R&D Funding for 1991

Although proposed funding increase seems sizable compared with the total federal budget, most of the total R&D increase is aimed at space station, Strategic Defense Initiative, AIDS, and other "big-ticket" items

Janice R. Long and Pamela S. Zurer, C&EN Washington

In his first comprehensive budget proposal to Congress, President Bush calls for increases in federal R&D funding that are much larger than the total budget increase of 3% to $1.23 trillion. For example, in the budget proposal, obligations for the conduct of R&D for fiscal 1991 would be up 7%, or $4.4 billion, over current levels, to $68.1 billion. Within that amount, obligations for civilian R&D would rise 12% to $26.7 billion, and obligations for defense R&D, conducted by both the departments of Defense and Energy, would be up only 4% to $41.4 billion.

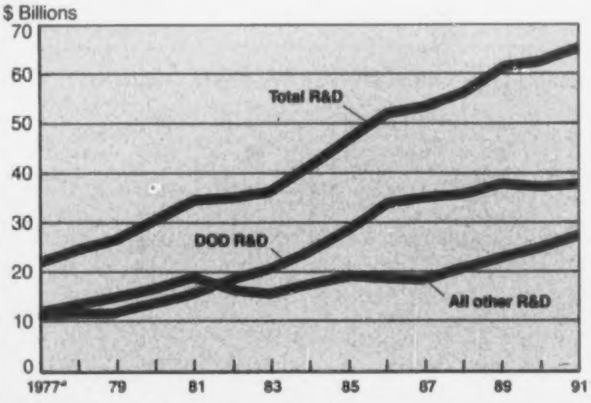
Total funding for basic research would increase 8% to $12.4 billion, accounting for about 18% of the total federal R&D budget. Civilian basic research would be up about 9% to $11.4 billion, and defense basic research would be up 6% to just under $1 billion.

An additional $3.1 billion would be earmarked for construction, repair, and modernization of R&D facilities, bringing total proposed federal support for R&D to $71.2 billion, an increase of 7% over fiscal 1990 funding levels.

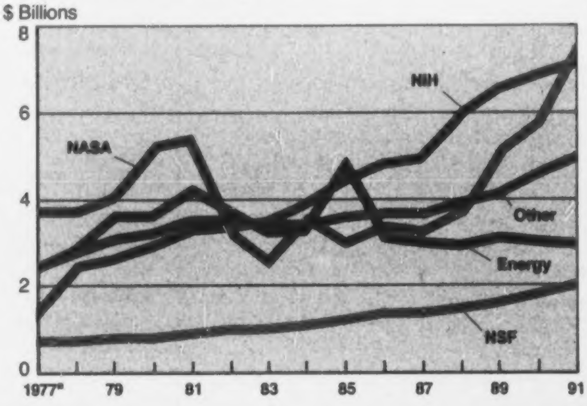
Although these proposed increases look quite healthy, in a relatively anemic budget, there are some caveats. First, over 70% of the increased funding for civilian projects is earmarked for a number of "big-ticket" programs. The fiscal 1991 budget, according to the Office of Management & Budget, calls for:

- A 36%, $699 million, increase to $2.6 billion for Space Station Freedom.
- An 18%, $531 million, increase to $3.5 billion for all aspects of the federal response—including research, prevention, and treatment—to acquired immune deficiency syndrome (AIDS).
- A 47%, $408 million, increase to $1.3 billion for

DOD's share of R&D spending falls to 57% . . .



. . . and NASA accounts for 31% of nondefense R&D



Note: Outlays. **Source:** Office of Management & Budget programs aimed at carrying out the President's goal of manned exploration of space beyond Earth's orbit.

- A 57%, $375 million, increase to $1.0 billion to ensure the U.S.'s world leadership role in climate change research.
- A 6%, $213 million, increase to $3.5 billion for biotechnology R&D programs.
- A 46%, $100 million, increase to $318 million for the Superconducting Super Collider.

Another "big-ticket" project, the Strategic Defense Initiative, accounts for 65% of the $1.4 billion increase slated for DOD's R&D programs.

Another caveat is that increases in R&D funding are being calculated from a deceptively low base. That's because to meet the fiscal 1990 deficit target Congress partially went along with an across-the-board cut in fiscal 1990 federal funding, including R&D funding, ordered by President Bush last October in accordance with the requirements of the "Balanced Budget & Emergency Deficit Control Reaffirmation Act of 1987." Bush had ordered cuts of 4.3% for defense programs and 5.3% for nondefense programs. Congress lowered those percentages to 1.5% and 1.4%, respectively, a lesser cut, but still a cut.

In addition, the President's budget proposal is only a starting point. It is Congress, through the authorization and appropriation process, that finally decides how much each agency can spend on what. In the early 1980s it was almost axiomatic that Congress would provide more money than requested for R&D programs, but that pattern has changed recently. Over the past three fiscal years, Congress has provided the total amount requested by the Administration for the conduct of R&D just once, providing 5% less than the requested level in the other two years. However, it did manage to provide slightly more, about 2%, than was requested for basic research.

The differences between the requested amount for agency research programs and what they

TOTAL FEDERAL R&D BUDGET PROPOSAL

Federal R&D funding breaks down like this

	Obligations			Outlays		
$ Millions	1991	1990	% change 1990–91	1991	1990	% change 1990–91
BY AGENCY						
Defense[a]	$38,714	$37,226	4%	$37,547	$37,064	1%
Health & Human Services	8,933	8,506	5	8,568	8,055	6
NASA	8,414	6,382	32	7,547	5,773	31
Energy	6,058	6,023	1	6,019	5,599	7
NSF	1,983	1,766	12	1,944	1,744	11
Agriculture	1,184	1,108	7	1,156	1,084	7
Interior	493	503	−2	499	469	6
EPA	460	431	7	435	393	11
Commerce	443	425	4	406	441	−8
Transportation	422	336	26	426	387	10
Agency for International Development	214	230	−7	289	306	−5
Veterans Affairs	201	215	−6	205	214	−4
Other agencies	621	561	11	592	556	6
BY FUNCTION						
Basic research	**12,366**	**11,398**	**8**	**11,886**	**10,961**	**8**
Civilian	11,372	10,459	9	10,911	10,016	9
Defense[a]	994	939	6	975	945	3
Applied R&D	**55,773**	**52,313**	**7**	**53,745**	**51,124**	**5**
Civilian	15,346	13,375	15	14,449	12,321	17
Defense[a]	40,427	38,938	3	39,296	38,803	1
TOTAL	**$68,140**	**$63,712**	**7%**	**$65,633**	**$62,085**	**6%**

Note: All numbers are estimates that exclude R&D facilities funding. a includes military-related R&D programs of the departments of Defense and of Energy. **Source:** Office of Management & Budget

Funding for basic research is up 8%

	Obligations			Outlays		
$ Millions	1991	1990	% change 1990–91	1991	1990	% change 1990–91
Health & Human Services	$4,993	$4,714	6%	$4,763	$4,483	6%
NSF	1,853	1,651	12	1,820	1,632	12
NASA	1,823	1,596	14	1,640	1,445	13
Energy	1,658	1,512	10	1,676	1,499	12
Defense-military	978	924	6	959	929	3
Agriculture	553	511	8	525	503	4
Other agencies	508	489	4	504	470	7
TOTAL	**$12,366**	**$11,397**	**8%**	**$11,887**	**$10,961**	**8%**

Note: All numbers are estimates. **Source:** Office of Management & Budget

Only three agencies get more money for R&D facilities

	Obligations			Outlays		
$ Millions	1991	1990	% change 1990–91	1991	1990	% change 1990–91
Energy	$1325	$1139	16%	$1195	$1057	13%
NASA	846	850	−1	720	628	15
Defense-military	458	639	−28	489	545	−10
NSF	153	119	28	75	64	18
Agriculture	103	118	−13	128	148	−13
Health & Human Services	96	77	25	60	77	−22
Other agencies	78	80	−3	71	70	1
TOTAL	**$3059**	**$3022**	**1%**	**$2738**	**$2585**	**6%**

Note: All numbers are estimates. **Source:** Office of Management & Budget receive has been greater. For example, the National Aeronautics & Space Administration has consistently received 7% less than it wanted for R&D. The Department of Defense's R&D budgets have been underfunded by 2 to 14%, and NSF has been coming in at 3 to 9% under budget. The Department of Energy's R&D funding usually has been right on target. The budget for the National Institutes of Health has gone from 23% above the requested level to 8% under and back up to 2% over its request. So it's hard to predict how Congress will respond to the current R&D budget request, except to say that changes will be made.

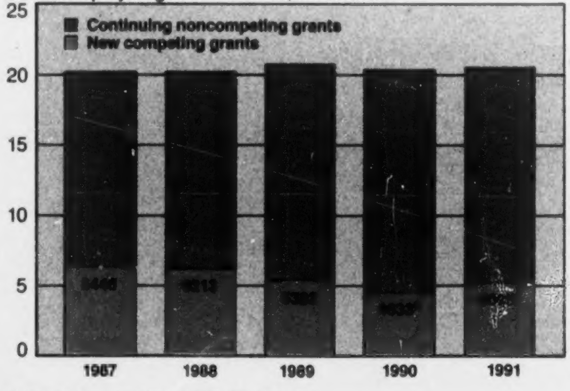
Defense Department. If Congress once again decides that DOD's R&D budget offers a tempting target for savings, it will fall well behind what is needed just to keep pace with inflation, which the Office of Management & Budget predicts will be running at a rate of 4% in fiscal 1991. That's exactly the percent increase being sought for DOD's research, development, test and evaluation programs in fiscal 1991, up 4% to $38.1 billion.

Funding for basic research, which actually fell 3% in fiscal 1990, would be up 6% to $978 million, but it still would account for only 2.5% of total RDT&E funding. In a briefing on the overall federal R&D budget, Presidential Science Adviser D. Allan Bromley said that the 6% increase was necessary to protect the U.S. "from being blindsided by technological breakthroughs during a time of reduced tensions" worldwide.

Bromley also said that it is extra important right now for DOD and the academic research community to rebuild their bridges of communication, which were disrupted during the 1970s when DOD was prohibited from funding any basic research not directly related to its military missions. He maintains that DOD needs contact with the bright young minds in universities, noting that the universities, in turn, can use its support. However, the 3% increase to $98.7 million requested for DOD's university research initiative won't provide for a whole lot of contact.

New grants from NIH have slipped from '87 high

Research project grants awarded, thousands



a Estimate. **Source:** National Institutes of Health

Basic research gets less than 3% of DOD R&D

$ Millions	1991[a]	1990[a]	1989[b]	% change 1990–91
Advanced development	$11,106.8	$10,340.3	$10,375.6	7%
Engineering development	10,941.7	11,301.9	11,413.2	−3
Operational systems development	9,759.9	9,219.1	9,416.9	6
Management and support	2,849.1	2,530.1	2,806.4	13
Exploratory development	2,457.5	2,403.1	2,540.8	2
Research	977.8	923.5	950.7	6
TOTAL	$38,092.8	$36,718.0	$37,505.6	4%

Note: Obligations. a Estimate. b Actual. **Source:** Department of Defense

Health & Human Services. Most R&D funding at HHS goes to the National Institutes of Health, whose budget Bush proposes to increase 5% to $7.9 billion. However, the added funds would not be distributed equally across all the research areas NIH supports. R&D addressing AIDS would rise 8% to $800 million, but the budget for mapping and sequencing the human genome would rise 82% to $108 million. If funds for those two areas are removed from the equation,

Human genome project up 82% at NIH

$ Millions	1991[a]	1990[a]	1989[b]	% change 1990–91
National Institutes	$7189.6	$6893.6	$6569.3	4%
Cancer	1694.1	1634.3	1572.9	4
(AIDS)	(160.8	150.3	124.1	7)
Heart, Lung & Blood	1112.5	1072.3	1046.3	4
(AIDS)	(44.5	42.1	38.6	6)
Allergy & Infectious Disorders	886.9	833.0	743.9	6
(AIDS)	(423.4	394.0	312.9	7)
General Medical Sciences	745.5	712.0	683.9	5
(AIDS)	(15.5	14.6	10.9	6)
Diabetes & Digestive & Kidney Diseases	605.4	581.5	559.9	4
Neurological Disorders & Stroke	512.2	490.4	472.7	4
(AIDS)	(17.2	16.2	13.4	6)
Child Health & Human Development	461.5	442.9	425.9	4
(AIDS)	(29.0	26.7	22.7	9)
Aging	248.9	239.5	222.9	4
Eye	247.4	236.5	231.4	5
Environmental Health Sciences	235.8	229.2	223.7	3
Arthritis & Musculoskeletal & Skin Diseases	176.1	168.9	160.1	4
Dental Research	140.5	135.7	131.0	4
Deafness and Other Communication Disorders	122.6	117.6	94.7	4
National Center for Human Genome Research[c]	108.0	59.5	28.2	82
Division of Research Resources	319.2	337.1	340.9	−5
Other	313.0	285.9	206.5	9
TOTAL	$7929.6	$7576.3	$7144.9	5%

Note: Obligations for AIDS research are included in totals for each institute. Subtotals for AIDS are broken out where they exceed $10 million. a Estimate. b Actual. c Previously included in budget of National Institute of General Medical Sciences. **Source:** National Institutes of Health basic research at NIH would get only a 4% increase—about even with the rate of inflation.

The overall NIH budget includes $4.4 billion for 20,439 research project grants—the primary source of funds for basic biomedical research—roughly 120 more grants than is slated for fiscal 1990. Perhaps as important to the research community, however, is a proposed increase in the number of new competing grants from 4633 in 1990 to 5095 in 1991. Last year the number of continuing grants that NIH was committed to funding put such a squeeze on new grant proposals that both researchers and NIH administrators were dismayed at the difficulty in getting a new grant funded.

The proposed 1991 figure is still well below the peak of 6446 new grants that NIH funded in 1987, but at least there is movement in the right direction. "Our heavy commitment base kept new starts down last year but this year probably won't be quite as severe," says Michael Rogers, program administrator in the National Institute of General Medical Sciences (NIGMS). "But it will be a continuing problem."

NIGMS, which accounts for about half of the NIH funds that support chemistry, would receive a 5% increase under Bush's proposal to $746 million for fiscal 1991. Within NIGMS, the pharmacological sciences program would increase 4% to $104 million; cellular and molecular basis of disease research would rise 5% to $205 million; and the biophysics and physiological sciences program would increase 5% to $152 million. Only $15.5 million, or roughly 2% of the institute's budget, would be directed to AIDS research.

Until the beginning of fiscal 1990, funding for human genome research fell within the NIGMS budget. In October 1989, however, the research project got its own center—the National Center for Human Genome Research—and thus its own budget, advisory council, and review panel. It remains to be seen whether Congress will agree to the full $108 million that the Bush Administration requested for the center this year. In fiscal 1990 Congress appropriated only $60 million of the $99 million requested.

National Aeronautics & Space Administration. R&D funds make up almost half of NASA's total proposed fiscal 1991 budget of $15.1 billion. And the $2.5 billion proposed for the controversial space station accounts for slightly more than one third of the total $7 billion R&D budget. That 43% increase, says NASA Administrator Richard H. Truly, is necessary if the agency is to launch the space station in 1995 and staff it by 1997—a schedule that has already slipped since last year.

Another program destined for big increases at NASA in fiscal 1991 is space research and technology, funding for which would rise 63% to $485 million. The funds would go toward developing new technology, including robotics, for science missions to the moon and Mars with the ultimate goal of manned trips to those destinations.

NASA also would be the big winner in Bush's proposed global-change research program. The budget requests a total of $1 billion, distributed among seven federal agencies, for research projects aimed at better understanding and predicting global change. Last year—the first that the interagency Committee on Earth Sciences pulled together a coordinated program—

Space station dominates NASA R&D budget

$ Millions	1991[a]	1990[a]	1989[b]	% change 1990–91
Conduct of R&D	$7017.7	$5499.9	$4327.9	28%
Space station	2451.0	1717.0	877.3	43
Physics and astronomy	978.8	910.5	787.1	8
Space applications	838.2	734.2	610.2	14
Space transportation capability development	762.8	679.6	707.0	12
Aeronautical research & technology	508.9	464.6	395.7	10
Space research & technology	485.4	298.7	297.2	63
Planetary exploration	480.5	388.8	425.5	24
Life sciences	160.2	105.6	83.1	52
Transatmospheric vehicle	116.0	57.7	71.2	101
Commercial programs	98.8	63.6	53.1	55
Academic programs	49.4	35.2	—	40
Exploration mission studies	35.2	—	—	—
Safety & quality assurance	32.5	24.7	21.2	32
Tracking & data systems	20.0	19.5	19.3	3
R&D facilities	99.0	112.6	23.3	−12
TOTAL	$7116.7	$5612.5	$4351.2	27%

Note: Obligations. a Estimate. b Actual. Source: Office of Management & Budget

Bulk of global-change research funds will go to NASA

$ Millions	NASA	NSF	NOAA[a]	Energy	USDA	Interior	EPA	Total budget
Climate & hydrologic systems	$302.5	$ 29.8	$67.6	$44.0	$ 2.1	$12.2	$ 3.3	$ 461.5
Biogeochemical dynamics	198.3	32.2	13.5	9.0	7.7	2.0	3.1	265.8
Ecological systems & dynamics	90.0	8.5	4.9	10.0	35.3	10.3	19.6	178.6
Solid Earth processes	63.0	12.0	0	0	0	5.9	0	80.9
Earth system history	0	9.0	1.0	0	1.1	8.0	0	19.1
Human interactions	0	5.5	0	3.0	1.2	5.3	0	15.0
Solar influences	7.2	6.0	0	0	0	0	0	13.2
TOTAL	$661.0	$103.0	$87.0	$66.0	$47.4	$43.7	$26.0	$1034.1

Note: Proposed budget for fiscal year 1991. a National Oceanic & Atmospheric Administration. Source: Committee on Earth Sciences global-change research got $653 million. Of the proposed $1 billion, $661 million would go to NASA, much of that directed toward its Earth Observing System program. This year's budget would fund the start of development of two polar-orbiting satellites that would take simultaneous, long-term measurements of many environmental features such as temperature, cloud cover, and ozone levels.

Research at other agencies that would be supported under the global-change umbrella include $103 million for NSF, mostly in its geosciences directorate; $87 million for the National Oceanic & Atmospheric Administration; $66 million within Energy; $47 million for U.S. Department of Agriculture; $44 million for the Department of Interior; and $26 million for the Environmental Protection Agency.

Energy Department. Research funding at the Department of Energy would grow 4% in fiscal 1991 to about $6.5 billion. R&D funding for atomic weapons and other defense projects, however, would rise only about 1%—a cut when inflation is taken into account—and other energy-related R&D would increase 6%. This reflects Energy Secretary James D. Watkins' belief that nondefense programs at his department were neglected during the previous Administration.

"During the 1980s our budget declined about 3% in real dollars," Watkins said while presenting DOE's budget. "Given that defense programs were growing, we mortgaged our future by throwing out too many other good programs."

Many of the R&D programs that fare the best in the budget proposal are tied to increasing energy efficiency and enhancing the energy supply, which are sure to be goals of the National Energy Strategy that is due to be released in April. For instance, funds for research on solar and other renewable energy sources would rise 25% to $175 million. And the budget asks for $183 million for conservation R&D, 10% less than Congress forced on the department for fiscal 1990, but a whopping increase over the $88 million the department proposed last year.

In basic research, the budget for the Superconducting Super Collider (SSC) would rise 46% to $318 million. That controversial "big-science" project is in for renewed scrutiny in Congress, as a major rethinking of its design will raise its cost at least $1 billion over the $5.9 billion total estimated a few years ago.

Despite the growing expense, however, Watkins is an enthusiastic supporter of the SSC. "If we can sell this program on its merits, this will be one of the most exciting science tools that the nation has ever come up with," he said. He also rebutted the criticism that the SSC is taking money that would go to other research, pointing to budget increases across the board for basic energy sciences and physics.

Those increases on paper can be deceptive, however. "It may appear that research budgets are going up, but the actual dollars available are remaining constant or declining slightly if you take inflation into account," says Robert S. Marianelli, director of the chemical sciences division in DOE's office of basic energy sciences.

Glossary of budget terms

Fiscal year. Year running from Oct. 1 to Sept. 30. The fiscal year is designated by the calendar year in which it ends.

Obligations. Commitments made by federal agencies to pay out money for products, services, or other purposes, as distinct from the actual payment.

Outlays. Payments for obligations incurred under Congressionally granted budget authority generally made by issuance of checks on the Treasury. Outlays during any fiscal year may be for obligations incurred in prior fiscal years or in the same fiscal year.

Note. The R&D numbers obtained from individual agencies frequently differ from those used by the Office of Management & Budget in preparing its analysis of total federal R&D funding.

Healthy increases are proposed for fiscal 1991 for both the chemical sciences division (up 8% to $151 million) and the materials sciences division (up 12% to $222 million). But Marianelli points out that the proposed increases must go to seven major user facilities that those divisions support. Given that Congress usually directs that certain pet projects be funded out of the remaining monies, Marianelli says the funds left to support research have remained about constant for several years.

National Science Foundation. The fiscal 1990 budget cycle was not a good one for NSF, but hope,

Clean coal, renewable energy gain at DOE

$ Millions	1991a	1990a	1989b	% change 1990–91
ENERGY R&D	$4005.1	$3788.5	$3387.5	6%
Basic research	2292.6	2009.0	1851.0	14
Basic energy sciences	648.7	569.8	549.3	14
Materials sciences	221.9	198.8	173.6	12
Chemical sciences	150.5	140.0	128.0	8
Other	276.3	231.0	247.7	20
High-energy physics	621.3	586.8	651.6	6
Biological, environmental research	339.2	314.0	266.5	8
Nuclear physics	330.8	290.8	256.8	14
Superconducting Super Collider	317.9	217.8	100.0	46
University research & instrumentation	34.7	29.8	26.8	16
Clean coal technology	372.0	214.7	42.4	73
Nuclear	357.8	341.8	347.0	5
Magnetic fusion	325.3	323.0	348.7	1
Fossil	202.3	445.2	377.9	−55
Conservation	182.6	202.3	178.3	−10
Solar and other renewables	175.1	140.5	152.2	25
Environmental safety and health	97.4	112.0	90.0	−13
DEFENSE R&D	2536.6	2507.5	2534.8	1
Weapons R&D, testing	1884.6	1863.8	1905.8	1
Naval reactors development	652.0	643.7	629.0	1
TOTAL	$6541.7	$6296.0	$5922.3	4%

Note: Obligations. a Estimate. b Actual.
Sources: Department of Energy, Office of Management & Budget

NSF's total budget is up 14% . . .

$ Millions	1991^a	1990^a	1989^b	% change 1990–91
Mathematical and physical sciences	$ 621.5	$ 557.0	$ 503.8	12%
Geosciences	383.7	325.0	309.9	18
Biological, behavioral, and social sciences	327.5	293.5	281.5	12
Science and engineering education	251.0	204.3	171.1	23
Engineering	226.0	200.2	187.1	13
Computer and information science and engineering	193.3	170.0	151.8	14
Antarctic program	175.0	151.9	131.1	15
Program development and management	102.5	96.4	91.3	6
Scientific, technological, and international affairs	74.0	63.5	58.3	17
Research facilities modernization	20.0	19.7	0	2
Office of inspector general	3.0	2.6	0	15
TOTAL	**$2377.5**	**$2085.1**	**$1885.9**	**14%**

Note: Obligations. a Estimate. b Actual. **Source:** National Science Foundation

. . . with funding for sciences up 10% . . .

$ Millions	1991^a	1990^a	1989^b	% change 1990–91
Ocean sciences	$ 171.0	$ 143.4	$145.9	19%
Physics	130.2	123.8	122.3	5
Materials research	123.5	116.9	115.1	6
Atmospheric sciences	120.1	104.1	98.6	15
Chemistry	103.4	97.9	96.7	6
Astronomical sciences	100.7	91.6	89.2	10
Mathematical sciences	73.7	69.1	66.0	7
Biotic systems, resources	73.4	66.7	62.8	10
Earth sciences	71.5	60.1	54.2	19
Cellular biosciences	63.1	57.3	55.5	10
Molecular biosciences	52.0	48.0	46.7	8
Behavioral, neural sciences	49.1	45.8	44.8	7
Social, economic sciences	35.5	32.3	30.9	10
TOTAL	**$1167.2**	**$1057.0**	**$1028.7**	**10%**

Note: Obligations. a Estimate. b Actual. **Source:** National Science Foundation

. . . and for chemical programs up just 6%

$ Millions	1991^a	1990^a	1989^b	% change 1990–91
Materials research	**$123.5**	**$117.0**	**$115.0**	**6%**
Project support	69.2	66.1	64.8	5
Laboratories and groups	36.9	34.6	34.2	7
National facilities	17.4	16.3	16.0	7
Chemistry	**103.4**	**97.9**	**96.7**	**6**
Physical	30.5	29.1	28.4	5
Organic and macromolecular	25.3	24.5	23.9	3
Inorganic, bioinorganic, and organometallic	17.2	16.2	16.0	6
Analytical and surface	13.7	12.9	12.7	6
Instrumentation	8.8	8.1	8.2	9
Special projects	7.9	7.1	7.5	11
Chemical and thermal systems engineering	**33.1**	**30.6**	**30.9**	**8**
Fluid, particulate, and hydraulic systems	9.2	8.6	8.8	7
Interfacial, transport, and separation processes	8.8	7.9	7.6	11
Thermal systems	8.1	7.5	7.8	8
Chemical reaction processes	7.0	6.6	6.7	6
Biochemistry	**14.7**	**13.8**	**13.5**	**6**
Cellular biochemistry	**13.6**	**12.2**	**12.0**	**11**
TOTAL	**$288.3**	**$271.5**	**$268.1**	**6%**

Note: Obligations. a Estimate. b Actual. **Source:** National Science Foundation

apparently, springs eternal. NSF started out the 1990 cycle intent on getting on track toward doubling its budget by 1992. It sought a 14% increase to $2.1 billion, including a 14% increase to $1.8 billion for research and related activities.

But Congress had other ideas. Although providing an almost 20% increase for science and engineering education in fiscal 1990 and requiring that a set amount of money be spent on a few research programs, Congress ordered across-the-board cuts in other research programs in NSF's appropriation bill. Those mandates coupled with the additional across-the-board cuts needed to meet the fiscal 1990 deficit reduction target, caused a "severe" crunch on the agency's budget, according to NSF director Erich Bloch.

So severe was the crunch that Bloch decided not to fund any of the 12 or so new science and technology centers that were planned for this year. Instead the center funds will be used to support individual research grants. Even so, NSF will be funding 4700 fewer researchers and graduate students than the 47,000 it had planned to support this year. Proposals for science and technology centers submitted in 1989 will be considered for funding in 1991.

Still, as the budget book says, this year's budget request of $2.4 billion continues progress toward doubling NSF's budget by 1993. And Bloch said, it's time for "Congress to make the investment needed" to reach the goal.

All this munificence hasn't yet trickled down to divisions of chemistry or materials science, even though they're part of a directorate—mathematical and physical sciences—whose funding is set to increase 11% to $622 million in fiscal 1991, following an 11% rise this year.

Funding for the chemistry division is slated to rise 5.5% to $103 million in fiscal 1991, after increasing just 1.2% this year. The new budget request is, in fact, $78,000 lower than that submitted for fiscal 1990. Still the chemistry division generally manages to fund about 58% of the proposals it receives and about 26% of all the proposals funded by the mathematical and physical sciences directorate each year.

In fiscal 1991, according to NSF budget documents, an increment of $2.11 million is targeted to increase support for graduate student research assistants. Another increment of $700,000 is intended for new, special-purpose instrumentation. An increase of $1.7 million will support 20 new investigators, and an increment of $900,000 will support continued growth in the 50-site nationwide program of research experiences for undergraduates. That takes care of the total $5.41 million increase requested for the chemistry division.

So the $1.2 million increase needed to fund additional interdisciplinary, interdivisional collaborative research in materials chemistry, chemical processing, and chemistry of life processes will, NSF says, "be provided by redirecting funds from more mature research activities" funded by the chemistry division.

Materials research doesn't fare much better than chemistry. Its budget is slated to increase 5.6% or

Agricultural research gets boost at USDA

$ Millions	1991[a]	1990[a]	1989[b]	% change 1990–91
Agricultural Research Service	$ 661.1	$ 601.6	$ 576.3	10%
Cooperative State Research Service	346.9	385.6	347.0	−10
Forest Service Research	150.2	149.6	139.8	0
National Agricultural Library	15.8	14.7	14.3	7
TOTAL	$1174.0	$1151.5	$1077.4	2%

Note: Obligations. a Estimate. b Actual. Source: Department of Agriculture

EPA emphasizes interdisciplinary research

$ Millions	1991[a]	1990[a]	1989[b]	% change 1990–91
Multimedia (interdisciplinary)	$111.4	$ 85.8	$ 44.3	30%
Air	94.9	77.8	67.7	22
Superfund	71.8	76.3	73.4	−6
Hazardous waste	41.2	43.8	43.5	−6
Water quality	28.9	26.7	24.1	8
Toxic substances	28.6	26.7	27.9	7
Drinking water	22.8	21.7	21.3	5
Pesticides	15.4	12.6	13.3	22
Management and lab support	15.4	14.4	12.6	7
Energy/acid rain	14.3	32.2	54.5	−56
Radiation	4.1	3.7	3.5	11
Leaking underground storage tanks	0.8	0.8	0.8	0
TOTAL	$449.6	$424.5	$386.9	6%

Note: Obligations. a Estimate. b Actual. Source: Environmental Protection Agency

$6.52 million, to $124 million, following a 1.6% increase this year. Its fiscal 1991 budget request, at least, is $283,000 over its fiscal 1990 request. In contrast to chemistry, materials research funds just about 44% of the proposals it receives.

The materials division is requesting an increase of $3.1 million to strengthen project support, $2.35 million to establish one additional materials research group, and $1.07 million for the national facilities and instrumentation program. Support for high-temperature superconductivity research wouldn't increase, remaining at $17.3 million.

And even though Congress gave NSF $20 million in the current fiscal year for research facility modernization, the foundation, according to Bloch, doesn't intend to spend the money right now. Instead it will combine that $20 million with the $20 million it is requesting in 1991 in one combined solicitation, awarding $40 million in fiscal 1991.

Department of Agriculture. There is no budget doubling in sight for the USDA. Bush is proposing only a 2% rise in R&D funding to about $1.2 billion for the department, not enough to keep up with inflation. Within USDA, the Agricultural Research Service would get the bulk of the increase, with its R&D budget growing from $602 million in fiscal 1990 to $661 million in fiscal 1991.

Although the R&D budget for the Cooperative State Research Service (CSRS) would actually decrease 10% to $347 million, the bulk of the cut comes from the buildings and facilities category. A key feature of the proposed 1991 CSRS budget is $100 million for competitive grants under a new National Research Initiative to fund research on plant and animal systems, global change, water quality, and human nutrition. Of the total, $15 million would support a program to map genomes of economically important crop plants.

The initiative was proposed in a 1989 report by the National Academy of Sciences, which suggested the program be funded at $500 million. Secretary of Agriculture Clayton K. Yeutter said USDA could not afford such a high amount now, but plans to increase the program $50 million per year in the future.

Environmental Protection Agency. One of EPA's priorities in fiscal 1991, says Administrator William K. Reilly, is "assuring sound science." EPA's research budget would rise just 6% to slightly less than $450 million. There is, though, a significant change in priorities. Funding for multimedia research, which used to be called interdisciplinary research, is slated to rise 30% to $111 million. This increase, EPA says, will allow it to anticipate environmental concerns rather than focus on short-term regulatory concerns.

Other big increases are slated for air research, up 22% to $94.9 million, and pesticide research, also up 22% to $15.4 million. A lot of the increased effort for air research will focus on such things as assessing exposure of the overall population to air pollutants and evaluating how alternative fuels affect air quality, human health, and the environment. Pesticide research will focus on potential environmental impacts of genetically engineered organisms and developing methods to prevent pollution from pesticide use.

National Institute of Standards & Technology. NIST is set to get the largest increase since its inception—as the National Bureau of Standards in 1901, that is. Its R&D budget would rise 22%, or $36.5 million, to $198 million. Acting NIST director Raymond G. Kammer says the requested increase "is long overdue," pointing out that NIST's funding has remained flat for the past 15 years.

The increased funds are spread over a variety of programs. For example, funding for chemical measurements and standards would be up $4.3 million, bioprocessing engineering up $2.3 million, high-temperature superconductivity research up $1.9 million, and high-performance composites up $1 million.

In addition, the 1991 budget contains funding for two technology transfer programs. The $10 million requested for the advanced technology program would provide grants to industry-led consortia for research in generic, precompetitive technologies, and the $5 million requested for the regional manufacturing technology centers program would provide matching grants to universities to establish centers for transfer of new and innovative manufacturing technologies to small and medium-size businesses. ☐

Chemical Industry Supports Favored Trade Treatment for U.S.S.R.

Most-favored-nation status would mean lower duties on imports from Soviet Union and a start to improving economic climate there

Earl V. Anderson,
C&EN Northeast News Bureau

The chemical industry has not yet joined the loud and growing chorus of voices from various U.S. business interests to extend most-favored-nation (MFN) tariff treatment to the Soviet Union. However, that's only because its international experts have been too busy with other trade issues. "Quite a few of our member companies strongly favor granting MFN to the Soviets," says a trade spokesman for the Chemical Manufacturers Association.

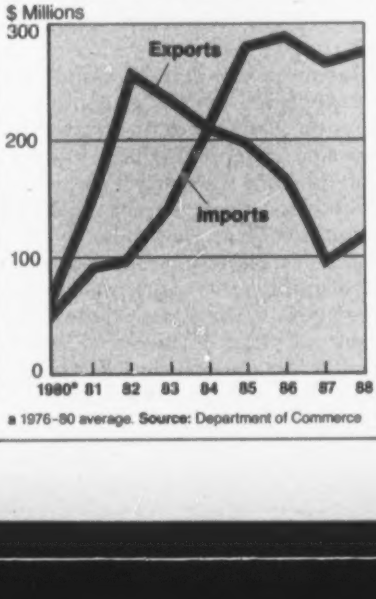
The National Foreign Trade Council, National Association of Manufacturers, and the U.S. Chamber of Commerce have all come out recently with strong statements supporting the move to grant MFN trade treatment to the U.S.S.R. If this were to happen, imports from the Soviet Union would enjoy duties that now exist on products from most other countries, rather than the punitively high rates that they now carry.

In a report released last month, the International Trade Commission (ITC) says it found strong support for such a move. It also says the action would have little or no negative impact on U.S. companies. In fact, most of the experts contacted by ITC believe that granting MFN status to the U.S.S.R. would have very little near-term impact of any kind on the volume of U.S.-Soviet trade.

But those statements belie the symbolic importance that MFN status would have on political and economic relations between the two superpowers. Granting such status to the U.S.S.R. would signal loudly and clearly that the U.S. has a long-term commitment to sound commercial relations with the Soviet Union. It would improve the climate for U.S. companies doing business in the Soviet Union and would increase the business opportunities for small and medium-size U.S. companies, not just the multinational giants.

Stacey J. Mobley, Du Pont's vice president for federal affairs, agrees. Granting MFN status to the Soviets, says Mobley, would cast a favorable political light on all commercial relations between the two countries. More important, he adds, it would put U.S.-based companies on a more equal footing with their counterparts in other western countries who are competing for growing opportunities in the Soviet Union. Indeed, some experts contend that MFN status is an absolutely necessary precursor to worthwhile U.S. investment opportunities in the Soviet Union.

U.S. exports of chemicals to U.S.S.R. top imports



a 1976-80 average. **Source:** Department of Commerce

MFN treatment is the cornerstone for most trade in the western world. Basically, it means that tariff concessions granted to one country will be granted to all countries.

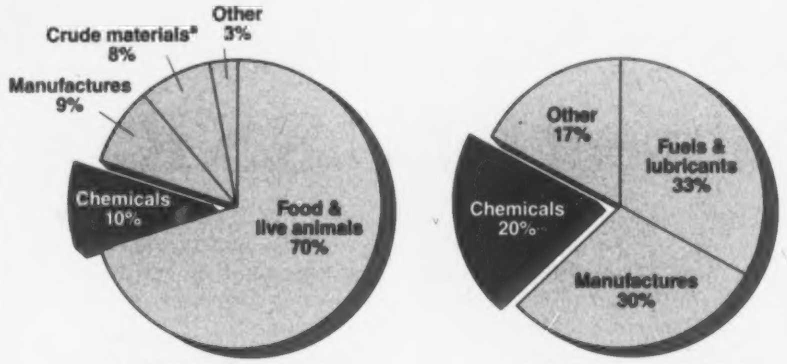
The Soviet Union has not enjoyed MFN status with the U.S. since 1951. A 1972 trade agreement between the two countries provided for such treatment and the president proposed that MFN status be granted to the U.S.S.R. as part of the 1974 Trade Act.

At that time, however, the MFN proposal was among the most controversial of all trade issues. Out of that controversy came the Jackson-Vanik amendment, which linked MFN status for communist countries to their willingness to allow free emigration. When the 1974 Trade Act passed with the Jackson-Vanik amendment intact, the Soviets terminated the 1972 trade agreement. As a result, it was never implemented and imports from the U.S.S.R. still do not enjoy MFN treatment.

Now there is a groundswell of opinion to grant the U.S.S.R. an exemption from the Jackson-Vanik amendment and to give it MFN status. So strong is that opinion, both in and out of government, that it almost certainly will happen, unless haggling over details sidetracks the main issue. Among the details: For how long should the exemption be granted and, rather than an exemption, should the Jackson-Vanik amendment be repealed entirely?

A U.S.-Soviet trade agreement is supposed to be ready by June. Presumably, MFN status will be a part of it. However, because of Administration officials' arguing over de-

Chemicals are important part of U.S.-U.S.S.R. trade



1988 U.S. exports to U.S.S.R. = $2.77 billion

1988 U.S. imports from U.S.S.R. = $578 million

a Inedible, excludes fuels. **Source:** Department of Commerce

tails of the agreement, actual negotiations haven't started yet.

Without MFN, imports from the Soviet Union must contend with the higher duties listed in "column 2" of the U.S. tariff schedules. In most cases, these so-called column 2 rates are much higher than the general, or "column 1" rates. For instance, the MFN duty on ethylene glycol is 12%. Its column 2 rate, however, is a hefty 63%. For polymers of ethylene, the tariff rates are 12.5% and 43%, respectively. For vinyl polymers, they are 10.1% and 43.5%.

These high column 2 rates make it difficult for Soviet products to compete in the U.S. and, along with past politico-economic tensions between the two countries, help to explain why trade with the Soviet Union is a small part of the overall U.S. trade picture. U.S. exports to the U.S.S.R. have only been about 1% of total exports for the past 10 years. Imports from the U.S.S.R. have been a miserly 0.1 to 0.2% of the total over the same period.

The same picture emerges in U.S.-Soviet chemical trade. It simply is not much of a factor in the overall trade picture. For instance, in 1988, the last year for which data are available, the U.S. exported $273 million in chemicals to the Soviet Union and imported $117 million in chemicals from it. Both are less than 1% of their respective totals.

Chemicals are, however, a very important part of U.S.-U.S.S.R. trade. In 1988, chemicals represented about 10% of U.S. exports to the Soviet Union. Without the overwhelming presence of agricultural exports, that figure would be 33%. Chemical imports were 20% of the total imports from the U.S.S.R. in 1988. And ignoring imports of petroleum products, chemicals' share also would be about 30%.

But for most companies that advocate MFN status for the U.S.S.R., an immediate boost in U.S.-Soviet trade is not the primary goal. As Du Pont's Mobley says, a much more important consideration is that it will make U.S. companies more competitive in the rush for business opportunities in the Soviet Union.

He notes that, for the most part, Du Pont's competitors for these opportunities are not other U.S.-based companies, subject to the same restrictions as Du Pont. Rather, most of them are based in Europe. Their business goals in the U.S.S.R. receive their governments' full political support.

Japanese competitors, says Mobley, approach the Soviet market differently. They try to undertake multifaceted projects to which they then will become the major suppliers. They also aim to be the ones that export the resulting products.

Mobley knows that focused, high-level political support for business ventures in the Soviet Union may have no place in overall U.S. policy. But he does believe that granting MFN status to the Soviets would be a positive first step.

Among the results of improved business relations with the Soviets could be more investment there. According to Mobley, Du Pont and its subsidiaries, mostly those in Europe, are "actively pursuing" joint-venture arrangements with groups in the Soviet Union. The most promising right now involve agricultural chemicals, automotive finishing, and oil production. All of them, says Mobley, involve mature, nonstrategic technologies that have significant market potential in the Soviet Union. And all of them meet the economic viability yardsticks that Du Pont applies to all of its investment deals.

Nevertheless, because the Soviets have no free market mechanism and because they always push for a countertrade arrangement in their joint ventures with western countries, it is difficult to apply those yardsticks to joint-venture deals in the U.S.S.R.

Granting MFN status to the Soviets won't, by itself, change the situation. But Mobley believes that it could help foster fundamental reforms in the Soviet economic system.

With those reforms, Du Pont's business with the U.S.S.R. could grow, along with those of other U.S. companies. In 1988, Du Pont sold $147 million worth of goods to the Soviets and bought $95 million. Last year, sales to the U.S.S.R. probably stayed at about 1988's level. But Du Pont likely imported about $150 million of Soviet materials in 1989—58% more than in 1988. Its purchases included energy, petroleum products, and basic chemicals. Among its sales: agricultural chemicals, plastics, elastomers, films, electronic materials, chemicals, and medicinal diagnostic products.

The natural market for products that Du Pont buys from the U.S.S.R. is Europe, Mobley says. However, the company has imported some Soviet products into the U.S., particularly organic chemicals. The Soviet Union, he points out, is a strong, competitive producer of petrochemicals, and Du Pont uses its products as raw material to produce downstream products. Soviet *p*-xylene is a case in point. Du Pont uses it to make polyester staple, film, and other polyester-based products. ☐

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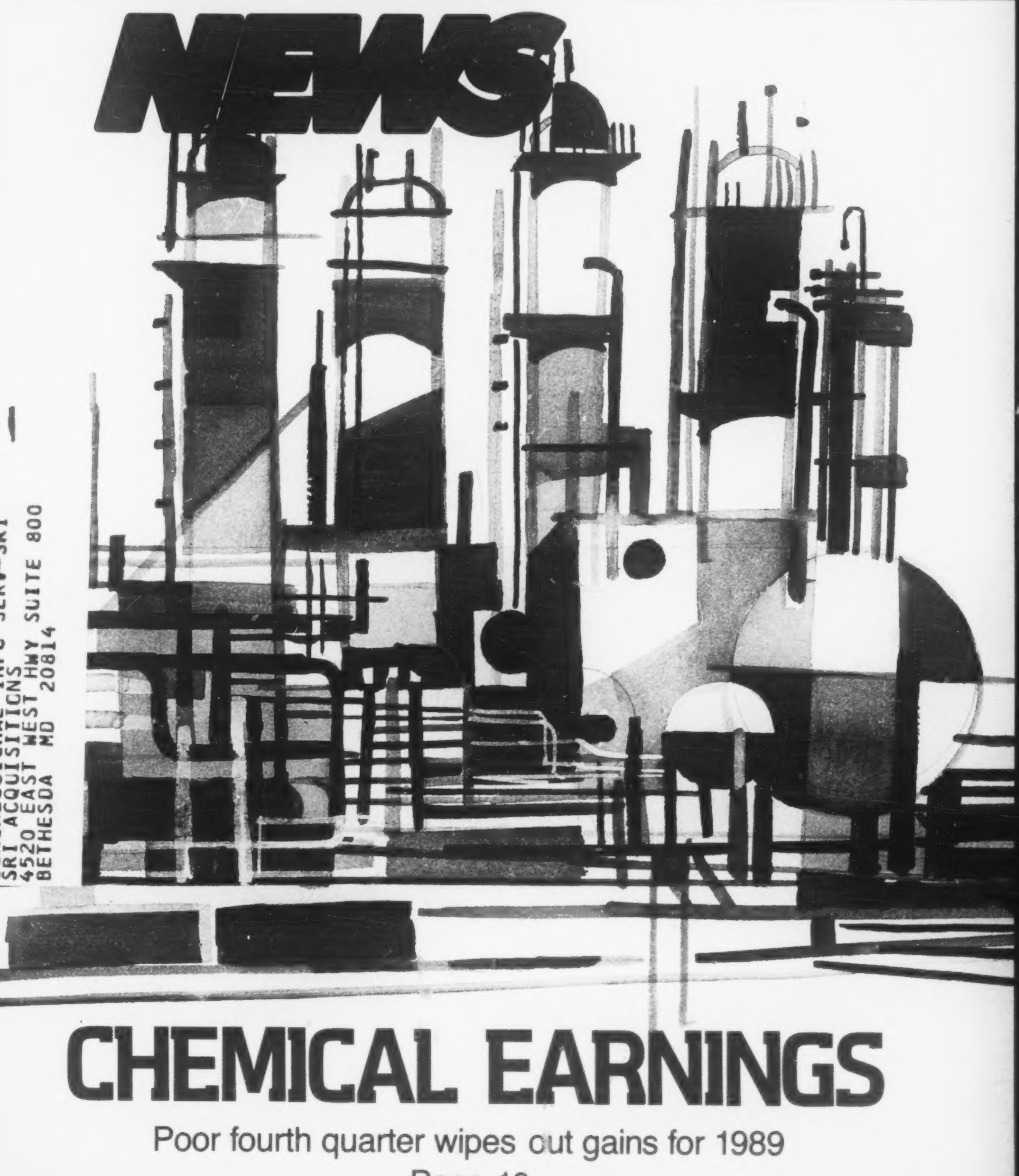
FEBRUARY 19, 1990

CHEMICAL & ENGINEERING NEWS



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CHEMICAL EARNINGS

Poor fourth quarter wipes out gains for 1989

Page 10

JACOBS 4/80

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CHEMICAL & ENGINEERING NEWS

FEBRUARY 19, 1990

News of the Week

- **In its biennial report, the National Science Board identifies weaknesses that raise serious questions about future health of U.S. science and engineering. Page 4**
- **A bilateral agreement paving the way for destruction of chemical weapons is almost sure to be signed by the U.S. and the U.S.S.R. this June. Page 5**
- **The benzene contamination that prompted the current recall of Perrier sparkling water was discovered by a U.S. lab that had been using it as a source of highly pure water. Page 5**
- **China expects its current austerity program and startup of new plants will help ease the domestic shortage of chemicals this year. Page 6**
- **University of California has sued Lilly for infringing a UC patent on genetically engineered human insulin. Page 6**

Business

Takeda U.S.A. has started up a vitamin C plant in Wilmington, N.C., one of the largest Japanese investments in the U.S. **Page 14**

Government

OSHA's new laboratory safety regulations stress employee training, development of chemical handling plans specific for chemicals used in individual labs. **Page 16**

Pesticide export policies would be modified, expanded under EPA proposal. **Page 17**

Regulatory agencies receive increased funding in Bush's proposed 1991 budget. **Page 18**

Science/Technology

New techniques that use readily available data to develop quantitative structure-activity relationships may facilitate environmental assessments. **Page 20**

Template molecule that catalyzes its own reproduction is product of aminolysis reaction. **Page 24**

Ultralight silica aerogel that could capture cosmic dust particles without destroying them developed. **Page 24**

Education

New residence hall, devoted to women majoring in science and math, opens at Douglass College, a campus of Rutgers. **Page 26**

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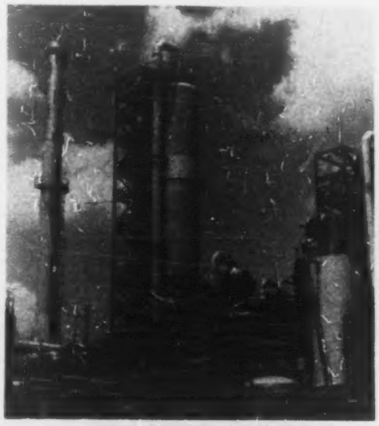

Cover Story

Earnings of major U.S. chemical firms tumbled in fourth-quarter 1989, largely because of increasing feedstock costs and slipping product prices, wiping out possible gains for the year. Page 10

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LETTERS

CHEMICAL SAFETY

Chlorosulfonic acid and heptane

SIR: John D. Baker reported (C&EN, Dec. 11, 1989, page 2) a violent reaction between chlorosulfonic acid and heptane. I believe there are four questions regarding this incident that were not reported: (1) Was the heptane wet? (2) Was the tank wet? (3) Did the heptane contain any olefinic impurities? (4) Did the tank contain any olefinic impurities?

In my research for the master's degree under the late George Holmes Richter at Rice University (1935–38), I studied the reaction between chlorosulfonic acid and 2-pentene. Contrary to expectations, this resulted in direct sulfonation, yielding a mixture of pentenesulfonic acids [*J. Am. Chem. Soc.*, **71**, 453 (1949)]. I learned quite early that chlorosulfonic reacted vigorously with water. In fact, even when disposing of unreacted acid in chloroform solution, the liquid was allowed to drip very slowly into ice water and each drop reacted with a pop and evolution of white fumes (presumably HCl, H_2SO_4 and/or SO_3, SO_2, and steam. It is well to understand that such a violent reaction would also occur with anhydrous alcohols and other oxygenates. Chlorosulfonic acid is a dangerous substance that must be handled with extreme caution.

Simon Miron
Petroleum Consultant
Lake Jackson, Tex.

Testing cosmetics

SIR: In Leland C. Clark's letter (C&EN, Jan. 8, page 3), he has resorted to indefensible logic and emotional blackmail in his support of cosmetic testing and his attack on the Animal Welfare Act. It is his opinion that since a few major cosmetic firms have stopped using animals in the testing of personal care products, the entire research community is threatened. Apparently we must defend their right to administer the Draize test to rabbits or legitimate research will surely suffer.

I, for one, do not consider such cosmetic testing as legitimate research. The Draize test, and other animal testing procedures, are performed not out of earnest scientific inquiry, but rather as a defense against anticipated litigation. In addition, the ability of these procedures, particularly the LD_{50} and the Draize test to predict human toxicity is being questioned with increased frequency. Clark's call for continued unrestricted use of the procedures does a disservice to research by undermining the impetus to develop more reliable and humane alternatives.

The Animal Welfare Act of 1966 (and as amended in 1970, 1976, and 1985), which Clark finds so distasteful, regulates the use of laboratory animals. It was originally promulgated to prevent the use of stolen pet dogs and cats for the purposes of research or experimentation. As amended, it further sets the minimum standards for the care and handling of laboratory animals. Among other things, it mandates that cages must have adequate heat, must allow for the removal of the animals' wastes, must allow the animals to comfortably stand, sit, or lie down, or otherwise move about. Other rules set similar minimum standards for feeding, ventilation, and watering. Where in here do we find the "police state mentality" he refers to?

The Institutional Animal Care and Use Committees (IACUCs), which he finds especially offensive, are another product of the 1985 amendment to the Animal Welfare Act. It stipulates that every federally funded research facility must have an active committee to oversee the use of animals in research. The IACUCs must have a veterinarian and a member of the community among its members. The sole function of the committees is to see that the regulations regarding animals are followed. They are not "given a free hand to run rough shod through research institutions."

The act and its provisions are hardly radical, and are not as cumbersome as Clark would have us believe. The act stipulates only the minimum standards that must be met, and falls far short of what most people would consider the humane treatment of animals. The regulations were borne out of an outraged citizenry over the continued, horrifying abuse of animals at the hands of a few researchers. Sadly, the regulations were needed because the research community failed to police itself.

By failing to distinguish between abusive cosmetic testing and legitimate re-

Correction

- Feb. 12, page 20: The bright line number, the number that separates reasonable from unreasonable risk, should be 10^{-4} not 10^{-6}.

Chemical Earnings, Profitability Dropped in 1989

William J. Storck,
C&EN Northeast News Bureau

Rising feedstock costs and falling product prices spelled trouble for many chemical producers in last year's fourth quarter. Earnings for major chemical companies and oil firms producing chemicals dropped from the year-earlier period, but earnings for diversified companies that produce chemicals and for pharmaceutical firms continued to increase.

For a group of 30 major chemical companies, combined earnings for the quarter fell 29% from fourth-quarter 1988 to $1.23 billion. Sales totaled $19.9 billion, about the same as in the year-earlier quarter. Profit margin (earnings as a percentage of sales) plummeted to a group average of 6.2%, down from 8.7% in fourth-quarter 1988 and down from 8.1% for the same companies in the third quarter.

Thus, chemical company earnings fell from double-digit increases in the first quarter of 1989 to double-digit declines in the fourth quarter.

Perhaps even more disturbing is that the fourth quarter, which is traditionally stronger than the third, when many companies shut down plants for maintenance, was considerably weaker this year. Sales for the fourth quarter were up less than 1% from the third quarter, but combined earnings were down almost 23%.

The decline in fourth-quarter earnings was enough to wipe out possible gains for the year. Through the third quarter, earnings for the group of 30 chemical companies were up 3% over the first nine months of 1988. But the decline in fourth-quarter earnings meant that

Chemical industry leaders for the fourth quarter . . .

Sales

Rank 1989		$ Millions	Rank 1988
1	Dow Chemical	$4264.0	1
2	Union Carbide	2085.0	2
3	Monsanto	2007.0	3
4	W. R. Grace	1719.2	4
5	American Cyanamid	1146.9	5
6	Hercules	773.4	7
7	Air Products	652.5	9
8	Ethyl	644.9	13
9	Quantum Chemical	626.7	6
10	Rohm & Haas	623.2	12

Earnings[a]

	$ Millions	Rank 1988
Dow Chemical	$427.0	1
Union Carbide	103.0	2
W. R. Grace	83.4	7
Arco Chemical	75.0	3
Ethyl	62.6	8
Monsanto	54.0	10
Air Products	49.4	5
Georgia Gulf	41.2	9
American Cyanamid	38.5	6
Nalco Chemical	32.6	15

Profitability

	Earnings as % of sales	Rank 1988
Georgia Gulf	17.0%	2
Great Lakes Chemical	13.9	1
International Flavors	12.9	7
Arco Chemical	12.4	3
Nalco Chemical	11.5	10
Loctite	11.1	9
Betz Laboratories	10.5	10
Dow Chemical	10.0	5
Ethyl	9.7	12
Vista Chemical	8.3	4

. . . and for full-year 1989

Sales

		$ Millions	Rank 1988
1	Dow Chemical	$17,600.0	1
2	Union Carbide	8,744.0	2
3	Monsanto	8,681.0	3
4	W. R. Grace	6,114.6	4
5	American Cyanamid	4,825.0	5
6	Hercules	3,091.7	7
7	Quantum Chemical	2,671.0	6
8	Arco Chemical	2,663.0	8
9	Rohm & Haas	2,660.9	9
10	Air Products	2,653.8	10

Earnings[a]

	$ Millions	Rank 1988
Dow Chemical	$2487.0	1
Monsanto	647.0	3
Union Carbide	629.0	2
Arco Chemical	405.0	4
American Cyanamid	292.0	6
W. R. Grace	256.6	12
Air Products	223.9	8
Ethyl	219.5	10
Georgia Gulf	200.0	11
Rohm & Haas	176.4	7

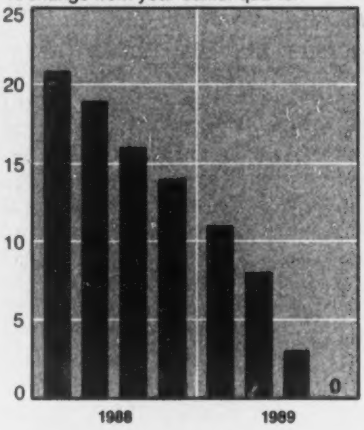
Profitability

	Earnings as % of sales	Rank 1988
Georgia Gulf	18.1%	2
International Flavors	15.9	6
Great Lakes Chemical	15.5	1
Arco Chemical	15.2	2
Dow Chemical	14.1	7
Vista Chemical	13.9	4
Loctite	12.3	9
Nalco Chemical	11.2	11
Betz Laboratories	10.8	10
Ethyl	9.0	12

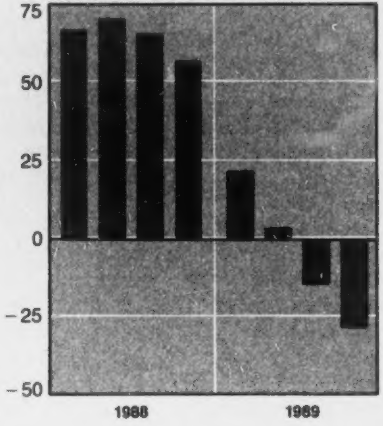
Note: Based on 30 chemical companies listed on page 12. a After taxes.

Chemical industry 1989 fourth-quarter results

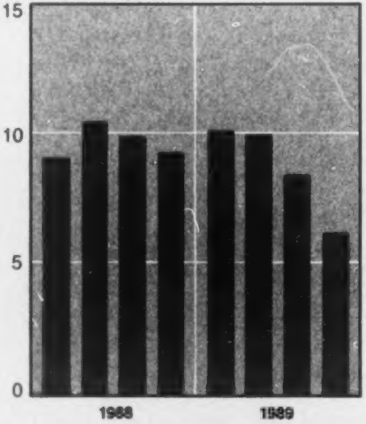
- Sales were nearly flat
- Earnings dropped 29%
- Profit margins fell to 6.2%
- Production rose 3.4%
- Prices up less than 1%


Sales

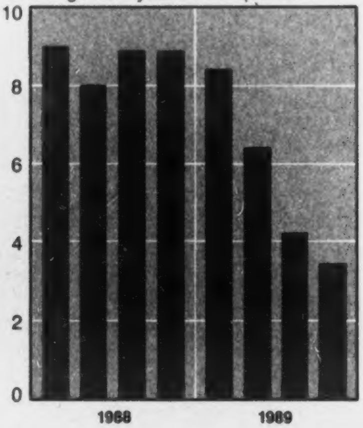
% change from year-earlier quarter


Earnings

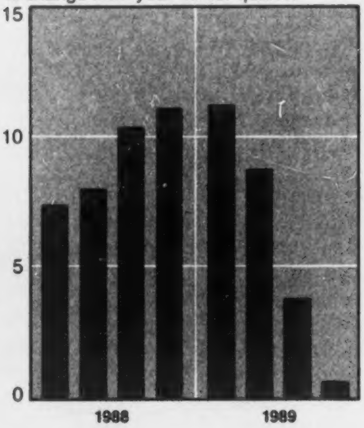
% change from year-earlier quarter


Profit margins

After-tax earnings as % of sales

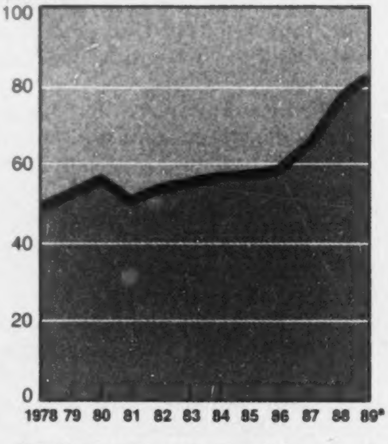

Production

% change from year-earlier quarter

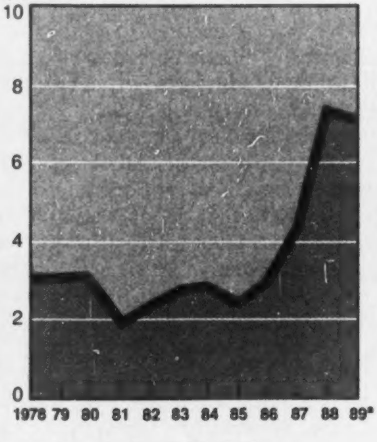

Prices

% change from year-earlier quarter

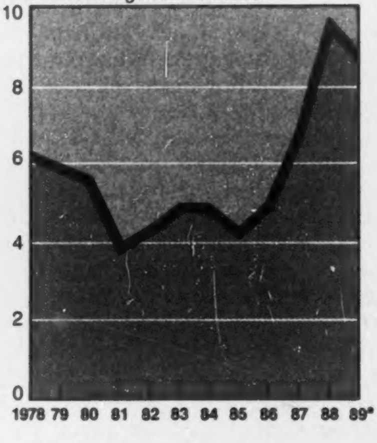
Sales in 1989 increased about 6% and earnings declined 4%, lowering profit margins to 8.7%


Annual sales

$ Billions


Annual earnings

$ Billions


Annual profit margins

After-tax earnings as % of sales

Note: All sales, earnings, and profit margin data are based on 30 companies on page 12. a C&EN estimates.

Earnings fell at most chemical companies in the fourth quarter

	FOURTH-QUARTER 1989						FULL-YEAR 1989					
	Sales	Earnings[a]	Change from 1988		Profit margin[b]		Sales	Earnings[a]	Change from 1988		Profit margin[b]	
	($ millions)		Sales	Earnings	1989	1988	($ millions)		Sales	Earnings	1989	1988
Air Products	$ 652.5	$ 49.4	2%	−19%	7.6%	9.5%	$ 2,653.8	$ 223.9	7%	2%	8.4%	8.8%
American Cyanamid	1,146.9	38.5	4	−37	3.4	5.5	4,825.0	292.0	5	−1	6.1	6.4
Arco Chemical	606.0	75.0	−19	−44	12.4	18.0	2,663.0	405.0	−1	−18	15.2	16.3
Aristech	222.6	15.1	−14	−57	6.8	13.5	996.4	82.1	−6	−50	8.2	15.4
Betz Laboratories	128.5	13.5	12	9	10.5	10.7	516.7	55.9	15	15	10.8	10.8
Cabot	406.6	18.4	−15	−19	4.5	4.7	1,863.5	51.9	5	−16	2.8	3.5
Chemed	145.6	5.7	0	55	3.9	2.5	591.8	26.2	18	27	4.4	4.1
Crompton & Knowles	85.1	6.0	−1	44	7.1	4.9	355.8	24.5	23	45	6.9	5.8
Dow Chemical	4,264.0	427.0	−1	−33	10.0	14.8	17,600.0	2487.0	6	3	14.1	14.4
Ethyl	644.9	62.6	11	14	9.7	9.5	2,430.0	219.5	16	13	9.0	9.3
First Mississippi	131.5	1.4	36	−77	1.0	6.3	489.2	8.3	48	−67	1.7	7.6
H. B. Fuller	189.6	5.1	5	5	2.7	2.7	753.4	15.7	10	−26	2.1	3.1
Georgia Gulf	243.2	41.2	−14	−24	17.0	19.2	1,104.5	200.0	4	3	18.1	18.3
B. F. Goodrich	573.7	28.1	−4	−30	4.9	6.7	2,419.7	171.2	4	−17	7.1	8.8
W. R. Grace	1,719.2	83.4	4	50	4.8	3.4	6,114.6	256.6	6	34	4.2	3.3
Great Lakes Chemical	226.2	31.5	59	14	13.9	19.4	792.3	122.9	42	19	15.5	18.5
Hercules	773.4	−26.9	3	def	def	0.9	3,091.7	103.6	10	−14	3.4	4.3
International Flavors	188.6	24.4	4	5	12.9	12.8	869.5	138.6	4	8	15.9	15.3
International Minerals	330.1	9.8	37	−35	3.0	6.2	1,165.8	69.7	23	−11	6.0	8.3
Loctite	121.7	13.5	8	10	11.1	10.9	473.9	58.2	8	22	12.3	10.9
Lubrizol	280.6	15.9	1	−35	5.7	8.9	1,227.9	94.0	9	15	7.7	7.2
Monsanto	2,007.0	54.0	7	20	2.7	2.4	8,681.0	647.0	5	9	7.5	7.1
Nalco Chemical	283.2	32.6	8	16	11.5	10.7	1,070.8	119.9	8	13	11.2	10.7
Olin	600.0	31.0	−4	48	5.2	3.4	2,509.0	124.0	9	27	4.9	4.2
Petrolite	75.1	3.5	1	64	4.7	2.9	291.4	12.1	−3	−7	4.2	4.3
Quantum Chemical	626.7	18.1	−22	−80	2.9	11.3	2,671.0	114.1	−9	−68	4.3	12.3
Rohm & Haas	623.2	21.4	5	−49	3.4	7.1	2,660.9	176.4	5	−23	6.6	9.1
Union Carbide	2,085.0	103.0	−3	−36	4.9	7.5	8,744.0	629.0	5	−5	7.2	8.0
Vista Chemical	170.1	14.1	−11	−55	8.3	16.3	757.7	105.6	−4	−17	13.9	16.1
Witco	379.8	14.3	−1	−30	3.8	5.3	1,587.8	78.2	0	−6	4.9	5.2
TOTAL[c]	**$19,930.6**	**$1230.6**	**0%**	**−29%**	**6.2%**	**8.7%**	**$81,972.0**	**$7113.1**	**6%**	**−4%**	**8.7%**	**9.5%**

a After-tax earnings from continuing operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. def = deficit.

total earnings for the year totaled $7.11 billion, down 4% from 1988. Sales for the year were still up 6% over 1988, however, to almost $82 billion. Profit margins slipped to 8.7% from 9.5% in 1988.

Lackluster end-use markets such as automobiles and housing had a negative effect on fourth-quarter earnings, according to some of the companies. Edgar S. Woolard Jr., Du Pont's chairman, noted softening in sectors of the economy important to the company. These included automotive, housing, and electronics, which, he said, depressed fourth-quarter results.

Dow Chemical cited price declines resulting from easing demand growth and increased supply in both ethylene glycol and vinyl chloride as well as softening in the North American construction market where products made from vinyl chloride are used extensively.

Export markets also had an effect on fourth-quarter earnings. Although chemical exports held up better than had been anticipated, industry sources say prices for exported products fell during the quarter. This was especially true for polymers and some large-volume inorganics.

The results of end-market forces ranged widely throughout the industry, especially in pricing. Government data show that prices of chemicals and allied products in the fourth quarter were up just 0.6% from fourth-quarter 1988. And prices were down 0.6% from the third quarter.

For the subcategory of industrial chemicals, which tend to dominate chemical company results, the price shifts were even worse. Industrial chemical prices for the fourth quarter averaged 0.6% below those a year earlier and were down 1.1% from the previous quarter.

Chemical production for the fourth quarter was still ahead, according to government figures, rising 3.4% from fourth-quarter 1988 and 1.1% from the third quarter of 1989. However, increases in capacity negated

Fourth-quarter earnings rose for drug and diversified companies, but dropped for oil firms

	FOURTH-QUARTER 1989						FULL-YEAR 1989					
	Sales	Earnings[a]	Change from 1988		Profit margin[b]		Sales	Earnings[a]	Change from 1988		Profit margin[b]	
	($ millions)		Sales	Earnings	1989	1988	($ millions)		Sales	Earnings	1989	1988
OIL AND GAS COMPANIES												
American Petrofina	$ 758.2	$ 13.5	12%	−59%	1.8%	4.9%	$ 3,036.4	$ 119.1	15%	−10%	3.9%	5.0%
Amoco	6,089.0	319.0	10	−15	5.2	6.8	23,973.0	1,610.0	13	−22	6.7	9.8
Ashland	2,200.0	22.0	5	−77	1.0	4.6	8,493.8	115.1	3	−56	1.4	3.2
Chevron	8,900.0	320.0	29	−27	3.6	6.4	32,800.0	1,458.0	13	−14	4.4	5.9
Exxon	26,550.0	1285.0	15	−7	4.8	6.0	96,076.0	4,655.0	8	−12	4.8	5.9
Kerr-McGee	798.9	37.2	16	11	4.7	4.9	3,087.1	156.0	15	42	5.1	4.1
Mobil	15,141.0	447.0	13	1	3.0	3.3	56,656.0	1,809.0	4	−11	3.2	3.7
Occidental Petroleum	5,049.0	30.0	−4	−42	0.6	1.0	20,068.0	256.0	3	−28	1.3	1.8
Shell Oil	5,505.0	264.0	1	25	4.8	3.9	21,948.0	1,405.0	3	13	6.4	5.8
Sun Co.	3,080.0	4.0	13	−96	0.1	3.4	11,380.0	275.0	14	−11	2.4	3.1
Texaco	9,241.0	389.0	9	−28	4.2	6.4	35,656.0	2,942.0	1	29	8.3	6.5
Unocal	2,852.0	66.0	7	−53	2.3	5.3	11,357.0	358.0	12	−3	3.2	3.6
TOTAL	**$86,164.1**	**$3196.7**	**12%**	**−17%**	**3.7%**	**5.0%**	**$324,531.3**	**$15,158.3**	**7%**	**−6%**	**4.7%**	**5.3%**
DIVERSIFIED MANUFACTURERS												
Allied-Signal	3,058.0	115.0	2	11	3.8	3.5	11,942.0	505.0	0	7	4.2	4.0
Borden	1,952.9	99.9	−2	6	5.1	4.7	7,593.4	343.8	5	10	4.5	4.3
Du Pont	8,993.0	483.0	8	−3	5.4	6.0	35,534.0	2,480.0	10	13	7.0	6.8
Eastman Kodak	4,886.0	465.0	8	49	9.5	6.9	18,398.0	1,404.0	8	1	7.6	8.2
Engelhard	626.3	14.5	−10	−25	2.3	2.8	2,403.0	82.9	2	30	3.4	2.7
FMC	822.7	32.4	−7	−10	3.9	4.1	3,414.5	156.8	4	21	4.6	3.9
Ferro Corp.	269.9	12.3	4	5	4.6	4.5	1,083.6	49.7	7	7	4.6	4.6
3M	2,954.0	292.0	7	7	9.9	9.9	11,990.0	1,244.0	6	8	10.4	10.2
NL Industries	239.4	20.6	2	−37	8.6	13.9	1,000.9	170.3	−1	27	17.0	13.3
PPG Industries	1,424.2	101.4	−1	−1	7.1	7.1	5,734.1	465.2	2	−1	8.1	8.3
Vulcan Materials	257.7	23.7	−4	−6	9.2	9.4	1,076.2	113.4	2	−17	10.5	12.9
TOTAL	**$25,484.1**	**$1659.8**	**5%**	**10%**	**6.5%**	**6.2%**	**$100,169.7**	**$ 7,015.2**	**6%**	**8%**	**7.0%**	**6.9%**
PHARMACEUTICAL COMPANIES												
A. H. Robins	1,455.4	253.0	11	14	17.4	17.0	5,379.8	859.8	9	14	16.0	15.2
American Home Products	1,640.2	304.4	7	19	18.6	16.6	6,747.0	1,102.2	5	11	16.3	15.6
Baxter International	1,961.0	139.0	7	15	7.1	6.6	7,399.0	446.0	8	15	6.0	5.7
Bristol-Myers Squibb	2,360.3	339.8	10	16	14.4	13.7	7,056.9	1,439.3	6	15	20.4	18.8
Merck	1,781.1	367.9	16	20	20.7	20.0	6,550.5	1,495.4	10	24	22.8	20.3
Pfizer	1,494.0	133.3	9	−6	8.9	10.3	5,671.5	727.3	5	−8	12.8	14.7
Rorer Group	403.5	44.7	24	66	11.1	8.3	1,182.2	86.5	13	40	7.3	5.9
Schering-Plough	776.9	111.1	5	20	14.3	12.6	3,157.9	471.3	6	21	14.9	13.1
Upjohn	727.9	80.2	4	−3	11.0	11.8	2,907.3	311.0	8	−13	10.7	13.3
Warner Lambert	1,043.4	92.3	5	19	8.8	7.8	4,195.8	412.7	7	21	9.8	8.7
TOTAL	**$13,643.7**	**$1865.7**	**9%**	**15%**	**13.7%**	**13.0%**	**$ 50,247.8**	**$ 7,351.4**	**7%**	**12%**	**14.6%**	**14.0%**

a After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales.

the effects of rising output. The government's measure for capacity use fell to 87.6% in the fourth quarter from 89.1% a year earlier and from 88.0% in the third quarter. The fall in capacity utilization, though still slight, helped to put pressure on prices.

One other factor that entered into the earnings picture for the fourth quarter was the unusually cold December weather along the Gulf Coast. This disrupted operations at a number of chemical plants, including those owned by Dow and Texaco.

Of the groups of companies surveyed, chemical companies (which derive 50% or more of their total sales from chemicals) showed the worst decline in fourth-quarter earnings. A group of 12 oil companies was the only other group surveyed whose earnings declined; their combined earnings dropped 17% to a total of almost $3.20 billion. Sales for this group increased 12% to $86.2 billion. Profitability for the oil companies was much worse than for chemicals, as it usually is; they registered an average profit margin of 3.7%, down from 5.0% in fourth-quarter 1988.

Petrochemicals fare poorly in fourth quarter

To get a picture of petrochemical performance, one can look at a chemical company such as Quantum Chemical, but a broader picture emerges from chemical earnings at the major oil companies, which are dominated by basic petrochemicals. And the picture in the fourth quarter is not very good.

Overall chemical earnings at eight large oil companies that report net earnings for chemicals fell an average of 48% in the quarter to about $674 million. This resulted in an 8% decline for the full year to about $4.52 billion.

Unocal, whose 88% decline in the quarter was the largest for the group, says its fourth-quarter results for chemical operations reflect higher fertilizer costs caused by temporary shortfalls of natural gas supplies and extended plant downtime for maintenance.

Texaco, which had the second largest decrease among the eight in the fourth quarter, says results were adversely affected by continuing price declines for olefins and derivative products. These declines resulted from a continuing oversupply of product in the marketplace. Plant disruption brought on by severe weather in December also reduced earnings about $15 million, the company says.

Exxon saw its earnings fall about 60% in the quarter and said that this was a result of rising feedstock costs and expanded industry production capacity.

Occidental Petroleum had the smallest decline, at 16%, which it says resulted largely from lower margins in petrochemicals, primarily reflecting lower sales prices industrywide.

EARNINGS ON CHEMICAL OPERATIONS

$ Millions	Fourth quarter 1989	Fourth quarter 1988	% change	Full year 1989	Full year 1988	% change
Amoco	$ 79.0	$ 145.0	−46%	$ 481.0	$ 684.0	−30%
Chevron	61.0	115.0	−47	378.0	455.0	−17
Exxon	136.0	340.0	−60	1080.0	1306.0	−17
Mobil	82.0	131.0	−37	573.0	613.0	−7
Occidental Petroleum	214.0	256.0	−16	1056.0	876.0	20
Shell Oil	84.0	193.0	−56	630.0	673.0	−6
Texaco	16.0	111.0	−86	268.0	245.0	9
Unocal	2.0	16.0	−88	49.0	51.0	−4
TOTAL	$674.0	$1307.0	−48%	$4515.0	$4906.0	−8%

Results from 11 diversified firms that produce chemicals showed an increase in earnings of 10% to $1.66 billion on a 5% sales increase to $25.5 billion. Thus the profit margin for the group increased to 6.5% from 6.2% in the fourth quarter a year earlier.

For the other group surveyed, 10 drug producers, earnings increased in the fourth quarter 15% to $1.87 billion on a sales rise of 9% to $13.6 billion. The profit margin for this group was 13.7%, up from 13.0% in the fourth quarter of 1988.

For this year, chemical producers are hoping that earnings have dropped about as far as they will go. They may be right in that 1989 third- and fourth-quarter earnings, which showed declines, were still being compared with very strong year-earlier quarters. First-quarter 1990 earnings will still be compared with a quarter that had shown a 22% year-to-year increase, but after that the comparisons will be made with quarters that were already showing signs of a slowing chemical economy.

If economists are correct in predicting the so-called soft landing for the U.S. economy instead of outright recession, the chemical industry, through 1990 at least, may well settle down to moderate sales and earnings growth. Moderation, however, will be a big change for an industry that up until the second quarter of 1989 saw earnings grow at more than 20% for 11 consecutive quarters. □

Takeda's vitamin C plant starts up

One of the largest Japanese investments in the U.S. chemical industry has begun operating with the dedication earlier this month of Takeda U.S.A.'s vitamin C plant in Wilmington, N.C.

The $90 million facility has a capacity of 11 million lb per year and boosts total domestic vitamin C capacity about 35%. Current U.S. capacity of just over 30 million lb is dominated by Hoffmann-La Roche's facility in Belvidere, N.J. The new Takeda plant will serve what the company sees as growing U.S. and Canadian markets, and its product also will replace imports of vitamin C from Japan.

At the dedication, Hirohiko Ichikawa, president of the fine chemicals division of parent company Takeda Chemical Industries of Osaka, Japan, said the new plant underscores the company's commitment to the U.S. He added: "It is an important step in our global strategy of expanding production and research capability in America, as well as Europe and Asia."

The new vitamin C unit is adjacent to a vitamin B-1 plant that Takeda U.S.A. has had in operation at its 1500-acre Wilmington site since 1985. Ichikawa said there are plans for more facilities at the site, but he was not specific about the type of plants and the timing.

Takeda Chemical Industries is Japan's largest pharmaceutical company and the seventh largest drug producer in the world. It also claims to be the world's second largest producer of bulk vitamins. In fiscal 1989 the company had total worldwide sales of $5.2 billion and R&D expenditures of $343 million.

For several years Takeda has had an R&D partnership with Abbott Laboratories to conduct clinical research in the U.S. on drugs created by Takeda. In 1989 this effort was restructured as a corporate entity under the name of TAP Pharmaceuticals. It is marketing Lupron Depot, a sustained-release preparation for the treatment of prostate cancer.

Michael Heylin

hazardous substances used there. If OSHA has a regulation for a specific carcinogen, such as for formaldehyde or ethylene oxide, the lab is obligated to follow those regulations.

The final rule gives no blanket exemption from the regulations to any kind of lab, unlike the original proposal, which exempted dental, veterinary, and group medical practice labs. OSHA has decided to redefine a lab by what it does and the volume of chemicals it uses. A lab, therefore, is a facility where the laboratory use of chemicals occurs.

Laboratory use is where chemical manipulations are done on such a scale that the chemicals can be easily carried and used by one person, where multiple chemical procedures are performed, where these procedures are not part of any production process, and where protective lab practices and equipment are in common use to prevent worker exposure to hazardous chemicals.

Other principal features of the new standard deal with employee training and medical exams. Training requirements have been beefed up relative to the proposed rule and are generally consistent with the provisions of the hazard communication standard. Employees must be trained to detect the presence or release of hazardous chemicals. They must be aware of the physical and health hazards caused by chemicals, and they must know what measures to take to protect themselves.

If an employee develops symptoms of a chemical exposure problem or if a leak or spill occurs, employers must give workers the opportunity for a medical exam. An exam is also warranted if routine surveillance shows that exposure to a hazardous chemical has gone over the action level or the permissible exposure level for that chemical.

OSHA does not yet have specific plans for enforcing the new laboratory standard. Like companies, labs probably will not have to send their chemical hygiene plans to OSHA for approval, but they will have to have them available for employee use. Neither does OSHA currently have plans for including laboratories in its scheduled inspections, but labs could be inspected in response to worker complaints about not complying with the regulation.

The complete standard, with explanations for some sections, is published in the Jan. 31 issue of the *Federal Register*, page 3300.

David Hanson

EPA seeks to amend pesticide export rules

The Environmental Protection Agency last week proposed changes to its pesticide export policies mandated under Section 17 of the Federal Insecticide, Fungicide & Rodenticide Act (FIFRA). The immediate goal of the changes, says EPA spokesman Al Heier, "is to bring our regulations more into concert with those of the United Nations and the Organization for Economic Cooperation & Development."

But the ultimate aim is to assure Americans that their imported food is untainted by exported pesticides not registered for use in the U.S. As assistant EPA administrator for pesticides and toxic substances Linda J. Fisher explains, "With these proposed changes, EPA will be more responsive to the concerns of the U.S. public that consumes imported food."

Many of the pesticides exported are not registered for use in the U.S. and, therefore, can't be sold here. However, these same pesticides may be sold to foreign countries once these recipient countries acknowledge and accept the fact that the pesticides are not registered in the U.S. But residues of these nonregistered pesticides may get back to the U.S. in imported food.

In addition to protecting the U.S. public, EPA also wants to make certain that recipient countries fully understand the U.S. status of exported pesticides. To that end, the agency proposes to amend its export policy for nonregistered pesticides. The agency also plans to clarify the labeling requirements for all pesticides—registered and nonregistered—made for export and to expand notifications to foreign governments whenever the agency takes a significant regulatory action on a pesticide.

EPA also is seeking disclosure of certain information that is now treated as confidential. It wants pesticide manufacturers to be required to divulge the final destination of their exported products. Now only the country to which a product is shipped is listed. But EPA argues that the final destination is usually publicly available information and therefore doesn't warrant confidential treatment.

Pesticide manufacturers disagree. Scott Ferguson, general counsel to the National Agricultural Chemicals Association, says the final destination may not be known to the exporting company. "In some cases the product is shipped to a warehouse or a brokerage house, from where it is subsequently distributed." Also, Ferguson says, even if the final destination is known, disclosing such information reveals important confidential marketing information to competitors.

Before exporting a pesticide not registered for use in the U.S., an exporter must obtain a signed statement from the foreign purchaser acknowledging this fact. This acknowledgment is eventually sent to the government of the importing country. EPA is proposing that these acknowledgment statements be multilingual—in English, in the language of the purchasing country, and in the language of the country

Five firms fined for unlawful pesticide exports

Dow Chemical, Midland, Mich.
Eight counts of exporting pesticides without proper labels
Assessed penalty: $22,400

Exxon Chemical Americas, Houston, Tex.
Seven counts of exporting pesticides without proper labels
Assessed penalty: $19,600

Mobay Corp., Pittsburgh, Pa.
110 counts of pesticide violations
Assessed penalty: $314,000

Rohm & Haas Bayport, LaPorte, Tex.
12 counts of pesticide export violations
Assessed penalty: $36,000

Shield-Brite Corp., Kirkland, Wash.
74 counts of pesticide export violations
Assessed penalty: $222,000

of final destination. Currently the statements are bilingual. EPA is also proposing that the label bearing the statement "Not Registered for Use in the U.S.A.," now bilingual, be multilingual.

EPA's Heier says, "EPA is trying to provide better information to the final using country. No effort is being made to prevent the exportation of U.S.-banned pesticides."

Ferguson admits the "objective of conveying necessary information to foreign governments and purchasers about risks is a good idea." But, he notes, "to have to make multiple translations is costly and difficult. And the language of international trade is English."

Currently EPA notifies foreign governments whenever a pesticide registration, cancellation, or suspension becomes effective or ceases to be effective. The agency is now proposing to expand these notifications to include other regulatory actions that affect human health and the environment. EPA also proposes to increase the frequency of these notices and to amend the transmittal process to bring these procedures into line with those adopted by the UN and OECD.

EPA's proposed amendments to Section 17 were published last week in the *Federal Register,* pages 4956 and 4967. Interested parties have 90 days to comment.

In a related matter, the agency has filed complaints against five companies for unlawfully exporting pesticides not registered for use in the U.S. The agency is assessing civil penalties totaling $614,800 against Dow Chemical Co., Exxon Chemical Americas, Mobay Corp., Rohm & Haas Bayport, and Shield-Brite Corp. Charges against these firms include exporting pesticides labeled only in English to countries in which English is not the official language, failure to obtain the foreign purchaser acknowledgment statement, and failure to label unregistered pesticides with "Not Registered for Use in the U.S.A." The firms have 20 days after receipt of the complaint to request an administrative hearing, institute an informal settlement conference, or pay the fines.

Lois Ember

Regulatory agencies' funding up in Bush's budget

Under President Bush's fiscal 1991 budget proposal, funding for the regulatory agencies that interact in one way or another with the chemical community is generally up by well over both the 3% rise slated for the government as a whole and the predicted 4% inflation rate.

For instance, the Office of Management & Budget points out that the 12% increase to $2.2 billion requested for the Environmental Protection Agency in fiscal 1991 is one of the largest requested for any government agency's operating budget.

Within that total funding for EPA, enforcement activities would rise 22% to $419 million. EPA Administrator William K. Reilly says this increase "serves notice that President Bush and EPA are committed to sustained, tough, predictable enforcement of the nation's environmental laws." The increase would allow for the addition of more compliance inspectors, attorneys, criminal investigators, and technical experts to the agency's staff. EPA says its goal is to ensure that complex civil environmental cases are litigated or settled under terms most favorable to the environment. And the agency says it will even more aggressively pursue enforcement of toxic waste cleanups by responsible parties.

According to budget documents, President Bush is expected to submit a legislative package of pollution prevention initiatives to Congress early this year. These will include a demonstration program to allow modification of existing statutory and regulatory requirements for generators of waste who can show that they can achieve greater protection of human health and the environment through pollution prevention and waste minimization efforts than through traditional approaches. EPA has allocated approximately $82 million of its fiscal 1991 operating budget for pollution prevention programs.

In addition to the operating budget, funding for the Superfund program would be up 14%, or $209 million, to $1.7 billion. That's on top of the 500 new people the agency expects to hire and the $75 million it expects to redirect to the program this year. The increase in monies for fiscal 1991 is expected to allow initiation of long-term cleanup efforts at 16 new sites. On the down side, EPA is seeking a 60% cut, to $14.2 million, in funding for nonpoint source control grants to states.

The Occupational Safety & Health Administration doesn't fare quite so well as EPA in the Administration budget proposal. Still, its funding would be up a respectable 8%, or $20.8 million, to $288 million. The increase includes $2.7 million for a targeted enforcement initiative; $3.2 million for a new integrated management information system; $4 million for ongoing redesign of the occupational safety and health statistical program; and $291,000 for the safety and health standards setting program. Funding for research by the National Institute for Occupational Safety & Health, however, is essentially frozen at $85.1 million.

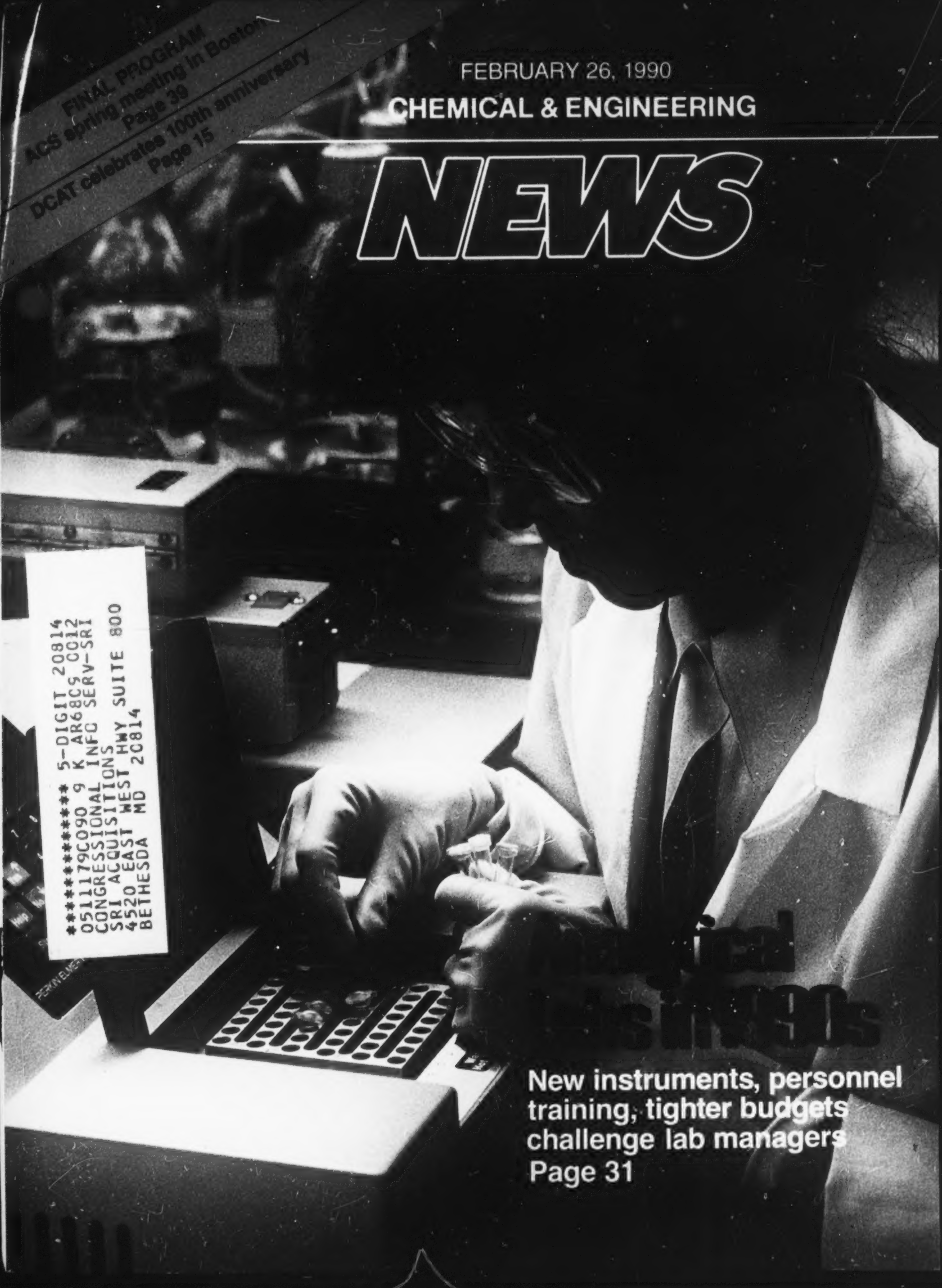
On paper, funding for the Food & Drug Administration isn't just frozen, it's down 9% to $528 million. However, according to Department of Health & Human Services' budget documents, FDA funding is actually slated to increase 14%, or $84 million, to $685 million. This discrepancy can be explained in that, although FDA is asking Congress for less money, it expects to raise $157 million through the collection of user fees imposed on companies that are seeking FDA product approvals.

FDA is requesting a total of $45 million for its generic drugs program, which has been plagued by revelations that several generic drug firms have provided fraudulent drug samples for tests to establish bioequivalence with the original drug. According to FDA, the additional resources will enable it to establish a separate office of generic drugs and reexamine a substantial portion of the 2000 generic drugs approved since passage of the Generic Drug Act in 1984.

Janice Long

FEBRUARY 26, 1990

CHEMICAL & ENGINEERING NEWS



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ACS spring meeting in Boston
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Analytical labs in 90s

New instruments, personnel training, tighter budgets challenge lab managers
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CHEMICAL & ENGINEERING NEWS

FEBRUARY 26, 1990

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- **First direct observation of rotation, vibration of a molecule made by California Institute of Technology chemists.** Page 5
- **Montedison chemist is arrested for allegedly stealing and attempting to sell trade secret for economically making fluorochemical lubricants.** Page 5
- **AAAS president, Richard C. Atkinson, places blame for shortfall in number of science Ph.D.s on academia.** Page 6
- **Biomedical researchers urged to counter efforts of animal rights activists at symposium held during recent AAAS meeting.** Page 6

Cover: Photo courtesy of Perkin-Elmer

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Business

Profitability is moving up again for PVC producers, as prices recover and demand strengthens for the widely used plastic. **Page 11**

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Drug, Chemical & Allied Trade Association marks 100th anniversary by noting the changes its membership, role have undergone. **Page 15**

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199th ACS national meeting in Boston in April will consist of some 4400 technical papers, a variety of social events, and an exposition. **Page 39**

Cover Story

Analytical labs in the 1990s will need faster, more precise, and less costly analyses while facing tighter budgets and a shortage of trained people to run the labs. Page 31

Chemical & Engineering News

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LETTERS

Transfer of funds

SIR: In the late 1930s an organization called the Pennsylvania Chemical Society was formed in Pennsylvania for the purpose of advancing the professional standing of chemists (C&EN, Jan. 10, 1940, page 33). The organization was closely allied to the American Chemical Society, and the membership included many of the leading Pennsylvania chemists of that era. The organization apparently became defunct in the early 1950s.

A few years ago the local Pittsburgh Section became aware of the existence of the Pennsylvania Chemical Society bank account and discovered that the account had escheated to the Commonwealth of Pennsylvania due to inactivity. The account has something in excess of $5000. I was approached in 1989 to try to recover these funds.

We have succeeded in recovering the funds. The purpose of this letter is to notify all interested persons that on April 17, 1990, at 9:30 AM, a petition will be presented in the Orphan's Court Division of the Court of Common Pleas of Allegheny County in Pittsburgh to obtain judicial approval for the transfer of these funds to the ACS Pittsburgh Section to be used for the forthcoming 1992 International Chemical Olympics to be held in Pittsburgh under the auspices of the ACS Pittsburgh Section. If any interested persons wish to object to the transfer of these funds they may present their objections to the court. Those who desire additional information can call J. Philip Bromberg, Attorney at Law, at (412) 471-2470.

J. Philip Bromberg
Pittsburgh

Business with China

SIR: I read with great interest your News Focus article, "China's Chemical Industry is Focus of ACHEMASIA '89" by Joseph Haggin (C&EN, Dec. 4, 1989, page 7).

On page 10 in the discussion of the ACHEMASIA representation, the author incorrectly points out that there were four American representatives. Three additional U.S companies were present during the entire show and were clearly identified as U.S. firms. These were Rainin Instruments, Emeryville, Calif.; Durametallic Seals, Kalamazoo, Mich.; and last, but certainly not least, Swenson Process Equipment Inc., Harvey, Ill. The writer and Tony Chao were present during the entire exhibition, and John Mulligan of WEGO General Trading Co. of New York, who represents us in China, was also present.

It is unfortunate that the U.S. did not initially make a heavier commitment to ACHEMASIA, and it is particularly regrettable that a number of the firms that did plan to attend turned out to be "no shows."

Swenson has been actively pursuing business in China for the past two years, and we have successfully negotiated contracts on six citric acid production facilities. While the Chinese are very tough negotiators, we have found that it is possible to sell successfully against European and Japanese competition. The low value of U.S. currency compared with the yen and deutsche mark at the present time means there is an unusual opportunity for American firms to be successful in world competition.

As long as the American appetite for foreign imports of all kinds remains at its present high level, it is essential for firms who can sell equipment abroad, particularly into Asia, to do so. I think the emphasis on horror stories in the article is somewhat overdone; however, there are significant differences in culture and the work habits in China, and some chemical plants in China leave much to be desired. On the whole, we are happy with our business relations in China and we think China will present a significant export opportunity for American companies for at least the next decade.

Richard C. Bennett
President, Swenson Process Equipment Inc.
Harvey, Ill.

DNA fingerprinting

SIR: John Thornton's report on DNA profiling (C&EN, Nov. 20, 1989, page 18) provided an excellent account of the history of forensic testing, the various tests now available for analysis of body fluids, and the use of DNA analysis in criminal cases and as biological evidence in paternity disputes.

As Thornton noted, DNA profiling is not infallible, and because it is technically demanding, there is a high incidence of human error. Yet, because of its use as evidence in court, the results of DNA

Correction

- Feb. 12, page 37: Gregory W. Ebert, PRF grant (Type B) awardee, is at State University College at Buffalo, not at SUNY, Buffalo.

Polyvinyl Chloride Profitability Starting To Turn Up

Prices of widely used plastic are recovering after falling steadily since mid-1989, paced by resurging demand and inventory rebuilding

Bruce F. Greek, C&EN Houston

Producers of polyvinyl chloride are beginning to smile again as prospects brighten for better times ahead. After prices for the widely used polymer plummeted last year, along with producers' profits, they're turning upward again. Further improving the immediate outlook is the likelihood of increased consumption this year, although by only a modest amount, boosted by strong exports.

Longer term, PVC is expected to maintain its position as the second most widely used plastic (low-density polyethylene is number one). However, it can't maintain that position without the improved profitability necessary for new PVC polymer development and further plant investments.

Another contributing factor, production costs, are under better control than they have been in the past, producers say. For instance, prices of PVC raw materials ethylene and chlorine declined last year, and recent process and product innovation has been accomplished inexpensively, setting the stage for broader product lines at lower cost.

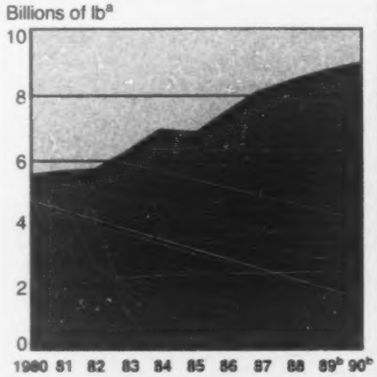
Despite recent price increases of 2 or 3 cents per lb for large-volume grades of PVC, no early return to the selling prices of a year ago is expected anytime soon. During the first half of 1989, selling prices for pipe-grade PVC resins typically were about 45 cents per lb, with other grades selling slightly higher. As ethylene prices began to slump last summer, PVC prices also declined. Late last year, but before the frigid weather along the Gulf Coast in December, pipe-grade resins were down 10 cents per lb or more, or 25% from earlier in the year.

The depressed prices for PVC resulted in major earnings declines in the fourth quarter and for the year for some PVC producers, such as B. F. Goodrich and Vista Chemical.

December's freeze caused damage to PVC production facilities in some areas, cutting five to 10 days' output from total annual production and further reducing inventories that had been falling through the second half of the year. Temporary shortages of some resins occurred ~~suddenly in~~ January, making a potential new round of surplus capacity less troublesome than it had been following the several announcements of capacity expansions in the preceding year.

For now, however, capacity expansions are expected to exceed growth in demand this year, making supplies more than adequate for all but the most specialized PVC resins. These expansions, expected to add 1.5 billion lb to nameplate capacity by the end of this year, will force down average plant operating rates this year and next. Occidental Chemical will complete the first of the 1990 expansions with its 200 million lb-per-year addition scheduled to start up at midyear at Pasadena, Tex. Two other major expansions—800 million lb by Formosa Plastics at Baton Rouge, La., and 500 million lb by Shintech at Freeport, Tex.—are scheduled to begin operating during the second half of the year. With Occidental's 100 million lb of additional output this year and the other two expansions probably adding about 300 million lb, 1990 potential production likely will increase about 400 million lb.

Demand for PVC will grow slightly this year



a Sales and captive use. b Estimate. **Sources:** Data compiled by Ernst & Young for Committee on Resin Statistics of the Society of the Plastics Industry, C&EN estimates

At the start of this year, U.S. PVC nameplate capacity using all the kinds of polymerization processes—suspension, emulsion, bulk (or mass), and solution—totaled about 10 billion lb. Last year, a combination of plant additions and process improvement projects added more than 750 million lb to U.S. capacity.

Of the 9.5 billion lb or so of actual capacity available last year, PVC production totaled about 8.6 billion lb, compared with about 8.4 billion lb in 1988. The average plant operating rate thus was barely more than 90%, down from the previous year's rate of about 95%, when PVC capacity was severely strained to meet demand. The capacity squeeze of 1988 began a yearlong increase in selling prices for PVC.

This year, PVC producers expect their output to increase about 2%. If production ends up totaling 8.8 billion lb or so, and average name-

Construction dominates PVC consumption

Millions of lb	Total sales and use[a]
Calendered products	769
Flooring	182
Textiles	100
Other	487
Coated products[b]	305
Extrusions	4299
Pipe (excluding fittings)	2513
Siding	656
Wire and cable	332
Packaging film and sheet	288
Other	510
Molded products	439
Bottles	182
Other	257
Paste process products	146
All other	451
Exports	708
TOTAL	7119

a Based on data through October 1989. b Includes flooring, textile and paper coatings, protective coatings, adhesives, and other. **Source:** C&EN estimates from data compiled by Ernst & Young for Committee on Resin Statistics of the Society of the Plastics Industry

plate capacity for the year increases to 10.5 billion lb, the year's operating rate will fall to about 84%.

Although PVC capacity after this year is harder to estimate—partly because some capacity may be shut down in light of its failure to compete economically with more technically advanced processes incorporated in expansions this year—it's clear that unless demand rises 10% or more (which now is very unlikely), operating rates may again decline in the early 1990s.

Meantime, producers' 2% increase in output this year will just match their expectation for a 2% rise in consumption (or slighty more if inventory building of fabricated products becomes significant). All of this growth is likely to come from demand in the U.S., with exports holding at last year's near-record level following a very large increase from 1988. Imports of PVC, at about 40 million lb, have little impact on total supply.

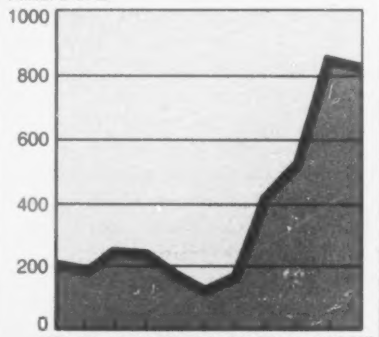
Demand for PVC in the U.S. last year declined more than 3% from 1988 to about 7.7 billion lb, according to Earl H. Simpson, manager of chemical analysis at Bonner & Moore Market Consultants. Much of the decline was in PVC pipe and fittings uses, but wire and cable coverings also contributed.

Total demand would have fallen even more had it not been for the large jump in PVC exports, particularly during the second half of the year. For all of 1989, Simpson estimates PVC exports totaled more than 850 million lb, up 330 million lb, or more than 60%, from 1988. Exports in 1988 also were up a significant 20% from the previous year.

Simpson doesn't expect the booming export market to continue, however, but forecasts a slow decline later in this decade as new PVC capacity comes on stream in other parts of the world, especially in the Far East. Although several of the announced capacity additions are large, their effect on U.S. exports likely will be minor because of construction delays and rapidly increasing demand for PVC in the countries where the plants are to be located.

This year's recovery in domestic demand for PVC will bring consumption back to about the level of 1988, or slightly less than 8 billion lb. The recovery will occur mainly in those uses that declined most in 1989—pipe and fittings, and wire and cable coverings. Use of PVC in siding and accessories, profiles used in windows, and in other residential exterior building products will continue to grow well above average rates. Siding and other residential construction uses were the brightest parts of an otherwise dreary 1989, posting an increase in demand of more than 10%, to more than 800 million lb and becoming the second largest domestic use of PVC, yet well below the pipe market.

Exports of PVC level off after recent strong surge



a Estimate. **Sources:** Data compiled by Ernst & Young for Committee on Resin Statistics of the Society of the Plastics Industry; C&EN estimates

Pipe and fittings, in fact, take more than 40% of U.S. PVC demand, or more than 3.3 billion lb. Last year, this use declined more than 5% as construction of homes and light commercial buildings eased. The fall in demand for PVC going into pipe and fittings exceeded the construction decline. When PVC pipe demand weakened during the usual summer lag before the seasonal slowing of construction, prices weakened, which also was usual. However, an image of too-high finished pipe inventories developed. As a result, not only were inventories of PVC resin grades for pipe reduced, but inventories of pipe also were sold off in anticipation of replacing them with less expensive pipe made with the less expensive PVC. The inventory liquidation grew, causing an annual decline of more than 13% in PVC going into pipe during October 1989.

This year's recovery in PVC demand for pipe and fittings is expected to make up only about 75% of the 1989 decline. Much of the growth is forecast to occur in making large-diameter pipe (typically 15 inches and larger) used mainly in municipal water and wastewater systems. This pipe, which has far greater wall thickness than the smaller sizes used in houses and commercial buildings, vastly increases PVC consumption per linear foot. Municipal construction continues to boost demand for PVC pipe, because cities and other entities are trying to catch up with demand for services and to replace worn out water facilities.

Other than the siding and window components applications of PVC, other uses are forecast to have a lackluster year in 1990. PVC's penetration in many product areas, such as wire and cable coverings, flooring, textile products, film and sheet for both packaging and nonpackaging uses, and bottles, likely has reached its maximum. In these areas, the plastic will do well to hold onto current levels of use. ☐

Analytical Lab Managers Brace for Challenges of 1990s

Developing new instruments, training enough personnel, and working within tight budgets are among potential problems they face

Joseph Haggin, C&EN Chicago

Changes have been sweeping analytical chemistry laboratories during the past decade and laboratory managers are now taking stock and trying to anticipate what will happen next. Several members of the Analytical Laboratory Managers Association (ALMA) recently examined the immediate future of the analytical lab in the U.S. They suggest that, while changes in instrumentation may not come so rapidly, other problems will severely tax the analytical community.

It is axiomatic that analyses will have to be faster, more accurate, more precise, and less expensive. They will also have to meet new requirements from more government agencies. Simultaneously achieving all these goals requires more than buying better instruments. The care and maintenance of instruments, as well as their organization, optimum operation, and location are equally important. The biggest problem of all may continue to be training enough people to design and operate the laboratories. And the problem of funding also looms, especially for academic R&D.

The "age of instrumentation" didn't begin just a decade or two ago, as some may think. Edward C. Olson, former director of the analytical lab at Upjohn Co., arbitrarily gives the honor to 1922. That's the year, he says, that carries the first reference to instrumentation in *Chemical Abstracts*. Before 1922, chemical instruments were referred to as "apparatus." Today's references are too numerous to count and they reflect the bewildering range of instruments available to the analytical chemist.

Olson suggests that one of the prime driving forces in the future development of analytical chemistry will be biotechnology. In particular, he points to the human genome initiative, now under way, which will "pour hundreds of millions of dollars into mapping the hundred thousand or so genes that have been identified." Far fewer have been adequately characterized. New instrumentation will continue to be needed for this project. Olson also thinks that international cooperation is essential. Every "scientific country" is involved and will have to cooperate to avoid unnecessary duplication.

The cost and duration of the genome initiative have been grossly underestimated in Olson's view. He also thinks relatively few new instrumental techniques will be developed but that massive refinement and proliferation of the present basic instrumentation will occur. Among the new developments he does foresee are truly monochromatic x-ray laser systems and high-intensity x-ray sources. Significant improvements should be made in the computational programs for x-ray structure, maybe even success in developing direct methods for determining macromolecular structure.

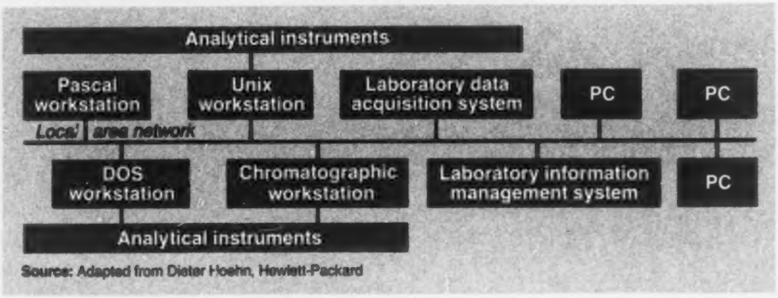
Unlike some observers, Olson does not subscribe to the need for ever-higher resolution in mass spectrometry (MS). He opines that most of the high-resolution mass spectrometers he is aware of don't operate anywhere near their maximum capability. He prefers more emphasis on ionization techniques that permit the vaporization of larger molecules.

Hewlett-Packard photo

Networked computer system is integral part of modern analytical lab

In the case of nuclear magnetic resonance (NMR) spectrometry, Olson doesn't foresee much immediate change. But he does see a need for greater resolution in electron microscopy, particularly for viewing organic molecules. Also, he suggests that infrared and ultraviolet spectroscopy and other optical methods of analysis have been developed to maturity. The same is true for electrochemical techniques and for gas and liquid chromatography (GC and LC).

Olson thinks that a new kind of organization featuring analytical centers will be used jointly by universities and industry. Cost will dic-



One concept of the unified laboratory

Source: Adapted from Dieter Hoehn, Hewlett-Packard

tate this. "We are now looking at instruments that cost a million dollars each," he says. "Not many organizations can afford multimillion-dollar instruments."

A different industry viewpoint is offered by Richard A. Dreher, president of RAD Associates, a consulting firm specializing in analytical laboratory development. Dreher contrasts the academic and industry views of paying for instrumentation as significant. The academics usually spread the cost of instrumentation over several projects, departments, and so forth. Industry is less inclined to do so. In addition, ever-greater government involvement in the marketing of new products often has made security of the data systems crucial.

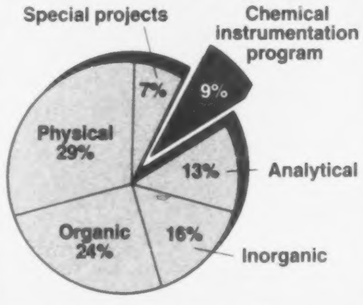
Dreher also suggests that the cost of networking will be a bigger budget item in the near future. In addition to the cost of the basic instrument, he says, software, computing, and report generation will add to the cost of operation. Necessary updates in hardware and software will compound the difficulties.

Industry puts great emphasis on productivity, with the biggest impediment at present being the time spent in sample preparation. Dreher considers the automation of sample preparation to be of prime importance.

In the immediate future, Dreher believes that tandem analysis, the sequential integration of several analytical procedures and instruments such as LC/NMR/MS, will become more common. A major impediment to tandem analysis is the lack of standard specifications in the hardware and software, particularly where international markets are involved. He has also discovered that personal computers (PCs) still are not really user-friendly, despite all the publicity to the contrary. He says computers simply don't make instruments easier to operate. Instrument/computer/people interfaces must be made truly friendly before any serious networking can take place, he believes.

Like Olson, Dreher emphasizes the rapidly growing importance of security. The precise time, technique, place, and procedures used in any given analysis will be subject to audits with increasing frequency. Labs have already seen a number of legal struggles that hinged on these audits. They will probably increase in frequency.

The viewpoint of the instrument maker was propounded by Dieter Hoehn, vice president and general manager of Hewlett-Packard Corp.'s Analytical Products Group. Among the principal trends he sees are the emergence of biotechnology, the hyphenated techniques (tandem analysis), distributed computing, and the gradual appearance of expert systems and robotics. He expects genetic engineering to be the driving force for some totally new kinds of instruments.



Instruments took 9% of NSF Chemistry Division budget

Fiscal 1989 total = $98.3 million

Note: Percentages do not total 100% because of one-time allocation to one science and technology center.
Source: National Science Foundation

If Dreher pointed to the yet-to-be-proven friendliness of PCs, Hoehn suggests that PCs have been responsible for the trend toward distributed computing, friendly or not. In any case, the modern analytical lab is growing less dependent on a centralized computing department and offers new room for flexibility in lab design and operation.

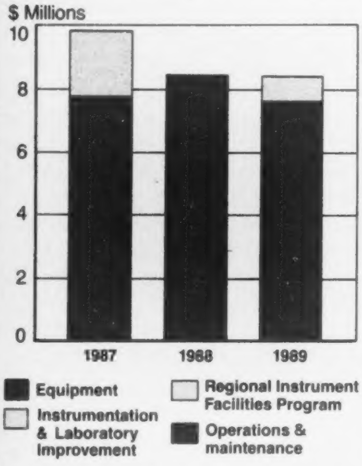
A major milestone in analytical instrumentation has been the emergence of Fourier transform infrared (FTIR) instruments, which were possible because of corresponding major developments in electronic chip manufacture and exponential improvements in machine computing.

The 1960s saw the emergence of individual instruments employing analog signal processing. The 1970s produced smart instruments and microprocessors. In the 1980s, labs moved from individual instruments to digital systems, where the emphasis was on information management. All the developments were driven by labor and computing costs. Computing costs declined about 30% but labor costs increased. At the present time, says Hoehn, the developmental and operational activities of analytical chemists are still driven by the same four considerations of the past three decades: the identity and amount of the analyte and the speed and accurate documentation of the analysis.

Hoehn says that lab managers are already experiencing a shortage of trained people to run the new labs. This shortage will become more acute and will tax their ability to provide and keep people with the necessary skills. Similarly, the sometimes bewildering requirements of environmental legislation make future costs and budgets very hard to estimate.

It is now certain, says Hoehn, that no single instrument maker can hope to satisfy all needs, if such ever existed. The broad-spectrum instrument supplier who tried to be all things to all customers is proba-

Hardware dominates instrumentation funding



Note: Funding by NSF's Chemical Instrumentation Program. **Source:** National Science Foundation

bly no longer in existence. This trend toward greater specialization brings with it some problems. One is the lack of industry standards at the user interface. As Dreher noted previously, this adversely affects productivity and makes software less than friendly. This also means that the instrument maker must pay more attention to training the user. Training times on new instruments are long, again adding to the productivity bind. The complexity of the systems must be reduced, Hoehn says.

Among the technology trends that Hoehn sees in the near future are smaller instruments (as a result of applying micromechanics) and ever more specific instruments. New detection principles could lead to higher sensitivity, he believes. It's significant, he adds, that the last 10 years have seen a reversal of the former trend of higher cost with higher reliability.

Hoehn expects to see a fundamental change in the industry in the area of sample processing and automation. The norm today is to move the sample into the lab for analysis. In the future, he explains, the sample will not be moved around; instead, data will be sent back and forth as required. Obviously, this will mean great data processing capability.

Hoehn foresees the future analytical chemist being increasingly occupied with his "workstation," a PC-based control center networked to the instruments and other stations of interest. Today, analysts mainly do instrument control data handling at the workstation. Some are already networked but they are usually rather primitive. He believes eventually there will be a global network that includes customers, suppliers, research contractors, and so forth. It will be important to integrate the necessary paperwork into the network, including the electronic laboratory notebook and archive functions. The analyst probably will also be networked into electronic mail and will have available databases for molecular modeling and statistical analyses, as well as personal databases. These workstations will have the computing power of the mainframe of a decade ago and there should be no need to study computer sciences to operate them.

Most of the analytical instrumentation necessary to make this prognostication a reality is already available. The big challenge in the near future is solving the engineering problems of integrating all the various capabilities to come up with what Hoehn calls his "total answer."

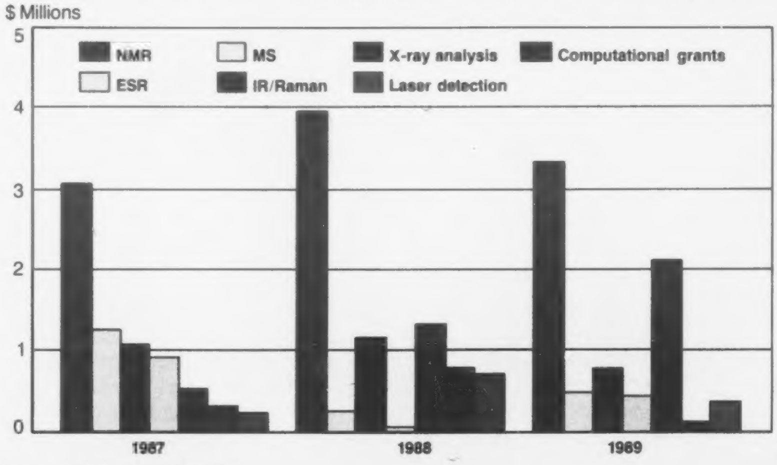
Hoehn acknowledges that his "dream system" has some significant limitations. One is the sensitivity limit that is specific to hyphenated analytical systems, networked into data-handling systems. There may also be particular functional groups, classes of compounds, or even elements that can't be determined yet. And analytical probability limits of 99% may be insufficient in the future. Finally, it will be very expensive.

Though these limitations may slow development of the "dream system" or any lesser system, they don't alter the development trends. A key datum seems to be the MIPS (millions of instructions per second) costs for data processing. The MIPS costs have been declining rapidly. In the near future laboratory desktop computers capable of 50 to 100 MIPS likely will become available.

Industry will continue to include analytical costs in its prices to customers. Academe must acquire funds in other ways. Two of the principal funding sources for the academic community are the National Science Foundation (NSF) and the National Institutes of Health (NIH). Each has evolving programs to encourage academic research. Unhappily, the total funds awarded are always less than those requested.

One of NIH's programs is the Shared Instrument Grant (SIG) program, established in 1982. SIG is targeted on large-scale, specialized research instruments that can be shared by different groups and is designed to complement other funding programs. SIG is intended only for individual instruments with

Chemical instrumentation program awards have dipped



Source: National Science Foundation

HERMIES IIB

Oak Ridge National Laboratory photo

U.S., Soviets discuss energy cooperation

HERMIES IIB robot at Oak Ridge National Lab is inspected by Soviet science officials (from left) Valeriy E. Anoshin, counselor, State Committee on Science & Technology; Aleksey N. Makukhin, first deputy minister of Energy & Electrification; and Vyacheslav M. Batenin, director, High Temperature Institute, Soviet Academy of Sciences. The trio was part of a nine-member high-level delegation that recently visited Washington, D.C., to discuss U.S.-Soviet cooperation in nonnuclear energy R&D and related trade opportunities, and toured Oak Ridge, the Department of Energy's Pittsburgh Energy Technology Center, and private-sector facilities. The two sides seek to renew an agreement signed in 1974, but let lapse by the U.S. in 1982 because of Soviet invasion of Afghanistan and the program's lack of benefit to the U.S. A DOE team will visit the U.S.S.R. in late March to continue talks.

price tags between $100,000 and $400,000. At least three users are required for 75% of the instrument's operating time.

In determining awards, SIG managers consider the extent to which an award would aid research already in progress or planned, how it would provide information not otherwise available, the presence of the expertise to operate and maintain the instrument, and the commitment of the institution to support the project and instrument.

In 1988, the largest number of requests were for NMR spectrometers (18%), gene machines (17%), electron microscopes (13%), and cell sorters (10%). These requests were received from institutions including health-professional schools, other graduate schools, hospitals, and research organizations. Foreign and private institutions are not eligible. More than 70% of the awards have been made to graduate and medical schools.

According to Marjorie A. Tingle, director of the Biomedical Research Support Program at NIH, SIG has received 1955 applications since its inception, with requests totaling $439 million. About 88% of the applications were approved and 77% of the dollars were recommended. Of the total applications, 1029 awards were made for $195 million.

The number of applications has increased 45% in the past two years. The 1989 budget was $105 million and Tingle doesn't expect it to increase. It may even drop, with a corresponding drop in awards. This is partially due to the emphasis on AIDS research that has the front row in funding at the present time.

Smaller grants are made by NSF's Chemical Instrumentation Program (CIP). Program director George M. Rubottom says the policy is for NSF to pick up two thirds of the acquisition cost for hardware, with the remaining one third being matching funds from elsewhere. Requesters can also apply for operations and maintenance grants of 10% of the instrument cost for up to five years, although the preferred payout period is 10% for three years.

NIH also considers requests for cofunding. If the cofunding institution is within NIH, the total request is jointly considered. This usually happens in the case of multidisciplinary research. For non-NIH cofunding sources the normal procedure of independent review is followed.

Rubottom says the success rate for proposals under CIP is about 50%. He expects this to decrease in the future mostly because the program is getting requests for more and larger instruments. In fiscal 1989, CIP allocated $8.4 million from a total budget of $98 million. Some of this went to regional facilities that will be phased out in the future.

However, a new program that promises to gain support is Instrumentation and Laboratory Improvement (ILI). This is for Ph.D.-granting schools that request funds to aid in education, that is, not for specific research activities. Rubottom expects the ILI program to be around for a long time because he notes, as have others, that education in analytical lab operation has lagged for years.

Most observers on the analytical scene touch on the matter of education. In general, they note that analytical labs are faced with a shortage of adequately trained personnel. No one contradicts this gloomy assessment. Few opportunities exist to train people to run an analytical lab. Instrument training is usually encountered in the normal course of instruction in progressive schools. It is often appended to regular courses, and not always well integrated into the curriculum. In industry, training often is part of an instrument-purchase package and, consequently, instrument specific. Updating the operating personnel is a perpetual problem and professional obsolescence is a growing problem. Continuous retraining is necessary.

One of the more unusual, possibly unique, programs for training analytical chemists is operated by John P. Walters, professor of chemistry at St. Olaf's College in Northfield, Minn. Walters refers to his program as a 20-year experiment that started at the University of Wisconsin in 1969 and moved to St. Olaf's in 1982. The experiment attempts to integrate ethics, small group dynamics, management skills, and the traditional vocational skills in analytical chemistry without the usual compartmentalization. For want of a better name, Walters calls this role-playing.

Walters' system begins in the freshman and sophomore years by developing the computer as an information management tool. This has the added virtue of countering some of the negative views of science that some young people have. Analytical chemistry itself is introduced in the junior year. Role-playing is the central feature of the laboratory exercises. The classes are divided into four roles: managers responsible for organizing the experiment, chemists responsible for manipulating solutions, "software" responsible for data collection, and "hardware" responsible for instrument selection.

In the senior year the same four roles are given different emphasis. Managers become more involved in experiment design, chemists become more involved in preparing solutions, hardware becomes more involved in assembling instruments, and software is more involved in processing data. The program at St. Olaf's emphasizes interdependence between skilled individuals and the division of responsibility, as opposed to the division of labor.

Walters claims that role-playing adds realism to an often deadly-dull lab course that traditionally stressed individual competition. He also says that in the role-playing ambience, students can make mistakes without becoming demoralized. □

British science journals are being revamped

This year the Royal Society of London's scientific journals are undergoing their first major reorganization in many years, the intention being to interest a broader international audience and to attract a wider range of prospective authors.

The changes include new procedures for submitting papers to the physical and mathematical sciences journal *Proceedings of the Royal Society of London, Series A*. Previously, a researcher had to contact a fellow or foreign member of the Royal Society and persuade him or her to communicate the paper to a journal.

"Clearly, for authors residing outside the U.K., that was not always an easy or convenient thing to do," says Michael E. Fisher, a professor in the Institute for Physical Science & Technology at the University of

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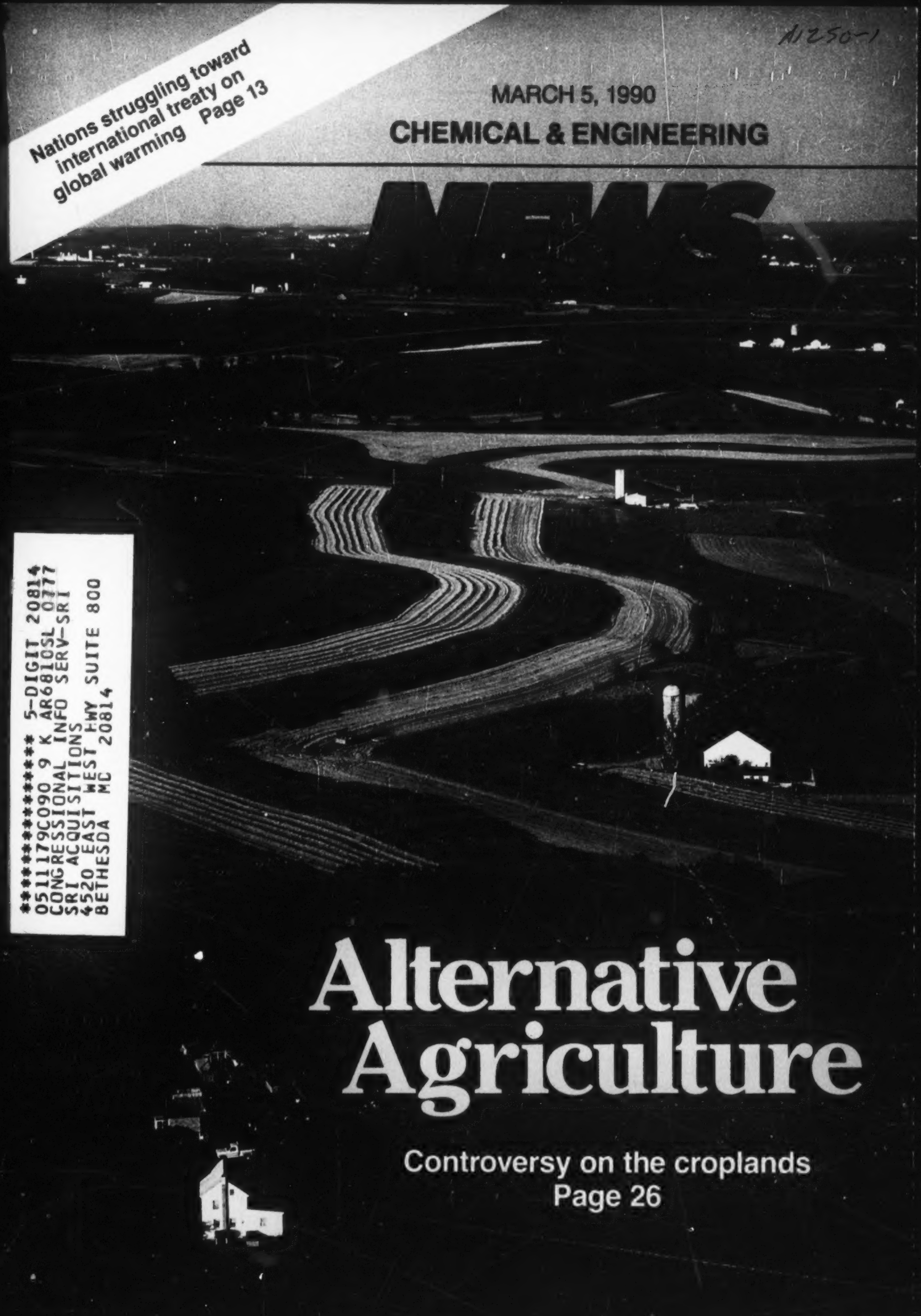
CHEMICAL & ENGINEERING
NEWS

Nations struggling toward
international treaty on
global warming Page 13



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CHEMICAL & ENGINEERING NEWS

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MARCH 5, 1990

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- **Governors' task force on global climate change gets conflicting advice from Administration officials, environmental groups.** Page 5
- **FDA approves Monsanto fat substitute for use in imitation ice cream.** Page 5
- **Industry assesses economic impact of clean air bills, says enactment will cause loss of at least 200,000 jobs.** Page 6
- **EPA's proposal to build hazardous waste facility in Edison, N.J., meets with overriding public opposition.** Page 6

Cover: Contour farming in Lancaster County, Pennsylvania. Photo by Larry Lefever, Grant Heilman Photography Inc.

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Business

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Affymax, a small, recently formed pharmaceutical firm, will target the drug discovery process. **Page 10**

The U.K.'s College of Petroleum Studies is significantly broadening its agenda. **Page 11**

Government

Negotiations heading toward international treaty on climate change are set to begin this fall, whether or not U.S. takes a forceful role. **Page 13**

Penalty for scientific fraud was probed in symposium on misconduct in science and the criminal law at AAAS annual meeting. **Page 15**

Flexible federal regulation that balances costs and benefits is stressed in President Bush's annual economic report. **Page16**

Science/Technology

Clusters and photochemistry were focus of "frontiers in chemistry" symposia at recent AAAS annual meeting. **Page 22**

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Chemist Carl Djerassi broaches misconduct in science from novelist's point of view in "Cantor's Dilemma"; "What You Need to Know to Live with Chemicals" focuses on toxicity to detriment of other issues. **Page 41**

Special Report

Alternative agriculture methods, though still used by only a minority of farmers, are attracting more attention and a growing number of adherents. **Page 26**

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LETTERS

Disposing of paints

SIR: Marc Reisch's product report, "Demand Puts Paint Sales at Record Levels" (C&EN, Oct. 30, 19[illegible], page 29), does a thorough job of covering market and new product trends in the paint industry. Unfortunately, it failed to address an increasingly important issue confronting paint manufacturers and users: proper disposal of used paints by retail-level consumers.

Paints pose the greatest difficulty, in terms of both quantity and expense, of any category of materials submitted by small-volume users (e.g., homeowners, small businesses) to local hazardous material collection and disposal programs. Informal surveys suggest that most paints are disposed of in environmentally unsound fashion by users who do not participate in such programs.

It is clear that some sort of action to increase compliance with safe disposal practices is needed soon. Among options being considered to cover the costs of suitable disposal and user education is a state tax applied to manufacturers who sell in Michigan. It is hoped that the paint industry, users, and C&EN readers will become aware of this concern as they develop, market, and use new products.

Dean W. Knuth
Kalamazoo, Mich.

Patent profitability

SIR: I have been a member of ACS for more than 50 years, and this is my first letter to the editor of C&EN. But a letter from William S. Lovell (C&EN, Aug. 14, 1989, page 3) compels me to reply.

I read his letter regarding patents and found it of interest as well as correct in a number of the points that he made in the course of his discourse. However, I feel that he is absolutely incorrect in one statement that he made as to the value of patents.

Lovell made the unqualified statement, "No patent, unless it has been licensed, has ever made anyone a dime (except, of course, for patent attorneys and the patent office)." Nothing could be further from the truth.

Most patents provide their greatest financial return to the patentee or owner in the higher degree of profit derived from the fact that the patent (assuming it is a good, protective one) allows the owner to get a higher price for his patented product than he would otherwise receive if the product was unpatented and open to cut-throat competition.

Some years ago I was chief patent counsel for a Fortune-500 company and had reason to do a comprehensive patent study covering all divisions of the company. The data provided by the study clearly showed that there was a direct correlation between the percentage of the products sold by a division that were covered by patents and the level of profit made by that division. In other words, the higher the percentage of patented products to total products sold, the greater the level of profit made by the division.

Also, when a company purchases another company having a substantial patent portfolio, the patents constitute an intangible asset that depreciates in value over the life of the patents, and can be used as a tax-deductible amount by the acquiring company in its corporate income taxes.

There are innumerable other ways in which valid patents can be of financial benefit to their patentee or the assignee owner.

Karl W. Brownell
Patent Counsel
Lewiston, N.Y.

Qualified Ph.D. candidates

SIR: Janice Long's article on alarms raised on the pending Ph.D. shortage (C&EN, Jan. 29, page 6) is reminiscent of similar concerns raised in the early 1970s and 1980s. As vice president of Epolin Inc., a small chemical firm, each week we receive dozens of unsolicited résumés from individuals who are either underemployed or unemployed—most of whom have exceptional qualifications. I would be pleased to offer our services and furnish these résumés, at no charge, to those companies and universities who claim not to be able to obtain quality candidates. Would any reader like to place a small wager on the number of replies I will obtain!

We are all aware of the large number of chemists and engineers that have lost their jobs during the past few years, many of whom have years of experience and could make a real contribution to science, but cannot find employment. This is the real national tragedy!

I would also like to hear from those universities that cannot find individuals to replace retiring faculty members. As an adjunct professor, I am personally aware of receiving in excess of 100 responses to a single advertised position. In a nutshell, there is no shortage, there never was, and I doubt that there will be into the 2000s.

International Negotiations Inching Toward Global Climate Treaty

Bush has been wary of radical changes in U.S. policy but other nations want action, and negotiations are set to begin in fall, whatever the U.S. role

Pamela S. Zurer, C&EN Washington

While U.S. policymakers hesitate to call for direct action to stem the accumulation of greenhouse gases like carbon dioxide in the atmosphere, other nations are pressing for concrete steps to avert global warming. Formal negotiations heading toward an international treaty on climate change are set to begin this fall—regardless of whether the U.S. takes a forceful role.

Despite promising when he was a Presidential candidate to fight the greenhouse effect with "the White House effect," President Bush has so far been wary of any radical alterations in U.S. policy. He and his chief of staff, John H. Sununu, believe that the scientific uncertainties surrounding global warming are too great to justify policies that would require changes in, say, fossil fuel use at costs that currently are difficult to quantify.

Instead, they stress strategies that make sense in and of themselves—such as increasing energy efficiency, banning chlorofluorocarbons (CFCs) that not only are greenhouse gases but also deplete the ozone layer, and reforestation.

According to a recent report by the General Accounting Office on the Administration's global warming policy, "Its early approach has been to proceed cautiously and defer specific new commitments until more is known about the validity and consequences of global warming." For example, Bush has refused to commit the U.S. to specific reductions in carbon dioxide emissions. Instead he stresses the need for more research on both scientific and economic issues.

In a speech last month to an international meeting on climate change, Bush once again emphasized the need for more knowledge before action. "Where politics and opinion have outpaced the science, we are accelerating our support of the technology to bridge that gap," he said.

Bush received a lukewarm response from his audience, the International Panel on Climate Change (IPCC). Set up in 1988 by the World Meteorological Organization and the United Nations Environment Program (UNEP), IPCC is charged with preparing a comprehensive report on the issue.

Delegates from 59 nations gathered in February in Washington, D.C., to review the progress of IPCC's three working groups. The U.S. chairs the response strategies working group; the U.K. heads the group responsible for reviewing and assessing the science relevant to climate change; and the U.S.S.R. chairs the group assessing the possible environmental and socioeconomic impacts of such change.

The response strategies being studied range from public education to technology transfer to legal measures—including a treaty on climate change. The UN General Assembly voted last year to start negotiations on such a treaty as soon as IPCC completes its report in August. And the Bush Administration has continually asserted that unilateral actions by the U.S. before the IPCC finishes its work would be counterproductive.

Climate change negotiations prompt plethora of meetings

February 1979	**1st World Climate Conference; Geneva**
October 1985	**International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts; Villach, Austria**
June 1988	Conference on the Changing Atmosphere; Toronto
November 1988	**1st Plenary Session, Intergovernmental Panel on Climate Change (IPCC); Geneva**
June 1989	**2nd Plenary Session, IPCC; Nairobi**
September 1989	Conference on the Global Environment and Human Response Toward Sustainable Development; Tokyo
November 1989	Ministerial Conference on Atmospheric and Climatic Change; Noordwijk, the Netherlands
December 1989	World Conference on Preparing for Climate Change; Cairo
February 1990	**3rd Plenary Session, IPCC; Washington, D.C.**
August 1990	**4th Plenary Session, IPCC, scheduled; Sundsvall, Sweden**
November 1990	**2nd World Climate Convention scheduled; Geneva**
June 1992	**UN Conference on Environment and Development, proposed**

Note: Meetings sponsored by United Nations agencies are printed in color.

IPCC's chairman, Bert Bolin, professor of meteorology at the University of Stockholm, stressed at the meeting that IPCC's function was to gather and assess information, not to recommend any specific policies for dealing with global warming. "It's not for us to express the political desirability or feasibility of how that will be done," he said. "But good data make it possible for nations to act."

Nevertheless, many of the delegates seemed bemused at best and more often annoyed by the persistent U.S. focus on the uncertainties in the science of global warming to the neglect of areas of agreement. For example, recent computer studies that show clouds might moderate global warming have received a lot of attention in the U.S. from some who would argue climate change is nothing to worry about.

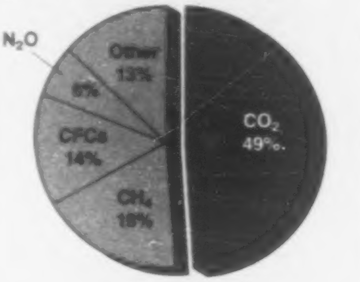
U.K. delegate Geoff Jenkins, speaking for the head of the science working group, referred to the debate about the cloud studies as "a domestic [U.S.] political dispute." Even including the newest cloud models, he said, the working group's assessment of the amount average global temperature will rise still ranges between 1.5 and 4.5 °C. That's the spread that has been generally accepted for about five years.

"Depending on the characterization of clouds in models," Jenkins said, "we can get different answers as to the effective temperature rise when you double the amount of carbon dioxide. But it would be unfair to say that the new results, which have lesser warming, are any more credible than the older results."

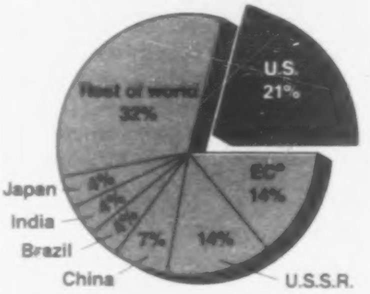
A similar point was made by Bolin in his remarks to the IPCC's opening session. "I am wondering sometimes why those that consider the projections to be overestimates of future changes are considered more 'sensible' by many politicians than those that worry about the upper part of the scientifically established uncertainty range," he said.

Bolin also said there is now a general awareness among nations about the threat of climate change and that the politics of the issue is entering a new phase. Countries are turning their attention, he said, to figuring out what to do to prevent and adapt to global warming—and what their positions should be in upcoming negotiations.

CO_2 contributes most to greenhouse warming . . .



. . . and U.S. emits the most greenhouse gases



Note: Estimated contributions calculated from atmospheric concentrations and radiative properties of gases. a European Community.
Source: Environmental Protection Agency

Many difficult questions will have to be hammered out if a meaningful framework convention—that is, international agreement or treaty—on climate change is to be achieved. Peter Usher, program manager of UNEP's environmental assessment project, says UNEP is preparing for negotiations to start in earnest this fall after the IPCC's report is presented to the 2nd World Climate Conference in November.

"How long it will take to complete negotiations, of course, depends on the type of agreement you are trying to reach," he says. "It must be acceptable to the greatest number of countries but at the same time be useful."

The negotiations that led to the Montreal Protocol on Substances That Deplete the Ozone Layer, which limits production of CFCs, are often proposed as a model for reaching an agreement on climate. The Montreal protocol, agreed to in 1987, is actually an attachment to a more general agreement called the Vienna Convention.

That agreement, completed in 1985, simply states that the nations of the world should protect the ozone layer. The specifics of how to do so were thrashed out separately, and with much greater difficulty, in the Montreal protocol negotiations. The road to a climate treaty might follow the same path: First a basic convention stating that global climate is worth protecting, followed by more exacting protocols spelling out how to do it.

But many nations, and UNEP itself, want a climate treaty with more teeth in it from the start. "The Vienna Convention is rather vague," says Usher. "We've grown up a little since then and we feel in UNEP there should be some specific obligations within the climate convention."

The requirements that UNEP would like in an initial treaty include the same "no regrets" strategies the Bush Administration advocates: energy conservation and reforestation. Targets for cutting emissions of greenhouse gases, while desirable, will be much harder to achieve, Usher says. "It obviously depends on the mood of countries at the time of the negotiations," he says. "Really specific obligations would be in separate protocols."

The climate treaty negotiations will face even more obstacles than did the Montreal protocol because every country has a stake in the outcome. "Developing countries did not play a significant role in the CFC issue; they are not big users," notes Alan Miller, executive director of the University of Maryland's center for global change.

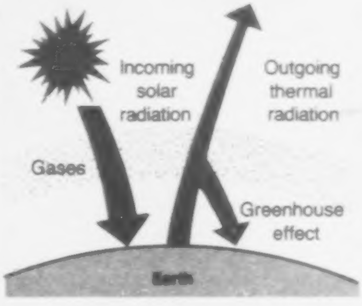
In contrast, China is already the largest coal-consuming country. And Brazil is intimately involved because of its vast tropical forests that are rapidly being cleared. Such deforestation removes a sink for carbon dioxide. The Eastern bloc countries also were not big players in the CFC negotiations, but are a large source of carbon dioxide. "Any effective agreement this time will have to involve very diverse interests," Miller says.

Some industrialized countries are already formulating their own national policies on reducing greenhouse gas emissions. Led by the Nordic countries and some members of the European Community, they are following a faster track parallel to the UN-sponsored IPCC process.

Those countries' more aggressive stances were highly visible last November at a meeting of environmental ministers convened by the Dutch government. Most of the 67 countries participating supported a proposal to reduce carbon dioxide emissions 20% by 2000—a proposition that was blocked by the U.S., U.S.S.R., and Japan. The meeting eventually agreed to a nonbinding declaration that acknowledges that greenhouse-gas emissions should be stabilized as soon as possible, but sets no emissions targets or timetable.

One of the most activist countries, Sweden, has already enacted legislation to freeze its carbon dioxide emissions at 1989 levels. That difficult task is made even more complicated by the Swedish government's 1980 decision to eliminate all nuclear power plants by 2010.

Greenhouse gases trap heat at Earth's surface



Scientists agree that:

- Certain gases are transparent to incoming solar radiation but absorb outgoing infrared radiation.
- Atmospheric concentration of carbon dioxide, methane, chlorofluorocarbons, nitrous oxide, and other greenhouse gases are increasing.
- As greenhouse gas concentrations increase, so will average global temperature.

Scientists have not reached a consensus on:

- Timing and severity of global warming.
- Regional distribution of impacts of climate change.
- Magnitude of feedback processes.

The Swedish parliament has been studying how to achieve the carbon dioxide freeze. One proposal being considered very seriously is a carbon tax—that is, fuels would be taxed based on the amount of carbon dioxide produced per unit of energy. In such a scheme, coal would be taxed more heavily than oil, which in turn would bear higher taxes than natural gas.

"If the ... proposals are implemented, Sweden will be the first country in the world to introduce a charge on carbon dioxide," says Maria Garding, a fuels specialist with Sweden's Ministry of Environment & Energy.

Carbon taxes are an example of the sort of economic incentives that could be used to encourage changes in fossil-fuel use. But greenhouse gases spring from a multitude of sources and controlling them all will be difficult.

Under certain schemes being discussed, however, not every country would have to control every greenhouse gas. The IPCC response strategies working group is studying the idea of emissions trading and the concept of carbon-dioxide equivalence.

Such ideas could benefit countries like Japan, for example, which has already reduced its fossil-fuel use significantly through new technology and energy conservation. If a climate treaty were simply to require, say, every signatory to cut carbon dioxide emissions 10%, it would be much more difficult and expensive for Japan to meet that goal than other industrialized countries that have not already made the easiest changes. Under more flexible schemes, Japan might be able to reduce methane emissions from rice paddies or pipeline leakage by an amount equivalent to a 10% carbon dioxide cut.

These sorts of nitty-gritty questions of how—as well as the sticky question of how much—to reduce emissions of greenhouse gases will be the grist for climate-treaty negotiators in the next few years. □

AAAS probes penalty for scientific fraud

"I do not think that it is a bad thing for persons who intentionally fabricate research data, and lie about their research data, to be told in no uncertain terms that this is wrong, not just in terms of some scientific ideal, but rather criminally wrong. It is fraud, just like embezzling money."

This sentiment, expressed by Harold Edgar of Columbia University, was the focus of considerable discussion at a symposium on misconduct in science and the criminal law at the annual meeting of the American Association for the Advancement of Science in New Orleans last month. Edgar is professor of law, science and technology, at Columbia's law school.

Although Edgar's line of thinking raises the specter of the heavy-handed involvement of criminal prosecutors in the practice of science, he received some support for his contention that scientists who commit fraud should be severely punished. For instance, *Science* editor Daniel E. Koshland Jr. stated that the very few scientists who do commit fraud should face very heavy penalties.

The Columbia lawyer explained that under Title 18 of the United States Code, Section 1001, two aspects of scientific misconduct—the intentional misreporting of research results and the intentional fabricating of research data—plainly constitute crimes when the person involved submits such falsehoods to the U.S. government in seeking, or reporting on, research grants. Plagiarism may, under certain circumstances, also be deemed criminal under this statute.

Although Edgar thinks the criminal prosecution of scientists who commit fraud may become more frequent, he also believes this will have several potential advantages for the science community.

First, in Edgar's view, there is far less chance that the criminal law will reach out to set norms for the practice of science in general than will the "administrative bureaucracy." Second, he believes that

SPECIAL REPORT

Alternative Agriculture

Bette Hileman
C&EN Washington

During the past year, alternative agriculture has suddenly become topical. Farmers practicing alternative agriculture are still a small minority in the overall farm community. But their farming methods, which among other things are aimed at improving profits, limiting dependence on agricultural chemicals, and increasing use of environmentally friendly procedures, are attracting more attention and a growing number of adherents. Hard data on the productivity of alternative farming compared with conventional techniques are still sketchy at best, although many practitioners seem to be operating quite successfully. And in their success lies the potential for significant impact on markets for fertilizers and pesticides.

When the National Research Council (NRC) published its report "Alternative Agriculture" last September, stories appeared on the front pages of newspapers across the country. Within an hour of the report's release, Charles E. Hess, the Department of Agriculture's (USDA's) assistant secretary of science and education, called it "of unparalleled significance."

And within a few months, a number of groups began condemning it. Dean R. Kleckner, president of the American Farm Bureau Federation, said it is being considered in Washington, D.C., "the new bible" of farming despite a lack of research on its tenets. Resources for the Future, a natural resources research group, called a news conference to argue that the NRC report had given an inaccurate and too optimistic view of both the environmental and economic benefits of alternative agriculture. The Potash & Phosphate Institute in Atlanta, Ga., wrote a lengthy criticism of it, saying it is biased and unscientific. Now, the NRC committee that wrote the report is preparing a response to its critics that will be released in a few weeks.

The major conclusion of the September NRC report is: "A small number of farmers in most sectors of U.S. agriculture currently use alternative farming systems, although components of alternative systems are used more widely. Farmers successfully adopting these systems generally derive significant sustained economic and environmental benefits. Wider adoption of proven alternative systems would result in even greater economic benefits to farmers and environmental gains for the nation." The report also says that the "scientific knowledge, technology, and management skills necessary for widespread adoption of alternative agriculture are not widely available or well defined."

There is a broad range of opinions about the NRC report and the movement toward alternative agriculture in general. But, in the past few months, thoughts about the subject have tended to polarize around two extremes: Proponents argue alternative methods must be adopted quickly to avert environmental catastrophe, whereas critics contend reduced pesticide and fertilizer use, encouraged by alternative farming methods, will lead to a loss in U.S. agricultural productivity and economic competitiveness and are, in any event, not justified by environmental or public health hazards. Farmers and legislators are caught in the middle of the debate, confused by claims and predictions of dire consequences coming from opposing sides.

Probably neither of these extreme views is realistic. Agricultural systems are quite resilient; soil and water resources can overcome many environmental insults. Catastrophies, if they come at all, are likely to happen after decades or centuries, not years. And farmers are

C&EN staff photo

by nature conservative. They tend to adopt new methods slowly and to abandon them quickly if they lead to a loss in productivity.

Although difficult to define precisely, alternative agriculture is a systems approach to farming that seeks to develop a multiyear practice that takes advantage of whatever is produced or can be produced on the farm, including naturally occurring beneficial biological interactions, to ensure soil fertility and to keep losses from pests, weeds, and animal diseases within acceptable levels. The aims are adequate productivity and profitability, conservation of resources, protection of the environment, and assured food safety.

A variety of means are used to achieve these ends, including expanded crop rotations and use of biological pest controls, soil and water conservation practices, and diversification in crops and livestock. For the majority of farmers, the reduction in purchased supplies is more an outcome of a shift in production practices than a goal in and of itself. No one practice or defined set of practices makes a farm alternative.

The vanguard of alternative agriculture in the 1980s has been farmers driven by economic necessity to cut production costs. Farmers who have designed new ways to raise crops and livestock that reduce purchased inputs by using them more efficiently and thereby protect the environment, are probably involved in alternative agriculture. Farmers aiming for profit alone by simply buying whatever seeds, fertilizers, and pesticides seem likely to produce the greatest yields, probably are not involved in alternative agriculture, though they could be using some of the same methods used in alternative agriculture. What sets alternative agriculture apart from conventional is the approach, not the specific methods.

Many critics say alternative agriculture is simply a return to the past. It is not. Though farmers involved in alternative agriculture have resurrected some methods from the past, what they are aiming to do is create a sustainable system using whatever means are available, both old and new, to reach their goals. Most of them are experimenting with new methods continually.

A number of different terms are used interchangeably to connote alternative agriculture—sustainable, low-input, ecological, and regenerative—but they basically refer to the same set of concepts. And when examples of alternative (or low-input) farms are mentioned they tend to be the same farms.

Alternative farms

Even though some critics may disparage alternative agriculture by saying that nearly all modern farmers practice it, most farmers who are using alternative methods contend they are definitely not involved in conventional farming. The majority have changed their methods in just the past few years. They frequently think of themselves as isolated—they are usually one of just a few farms in their townships or counties using these techniques. Many have formed groups—the Practical Farmers of Iowa or the Illinois Sustainable Agriculture Society, for example—to share ideas, learn from each other, and relieve the loneliness of belonging to a small, but growing, minority.

Even the superficial appearance of farms that use alternative methods often differs markedly from that of other farms. For example, one of the best-known farms using alternative methods, Rhichard Thompson's in central Iowa near Ames, is the only one in the neighborhood that has livestock. Suddenly, in a dead-looking winter landscape of snow-covered fields broken only

Tom Frantzen photo

Narrow rows of corn, soybeans, and oats, planted on ridges, follow the land's contours, helping to prevent erosion on this Iowa farm

by an occasional house and collection of farm buildings, cows can be seen ambling on Thompson's fields—even when the temperature is -10 °F. Young pigs bursting out of small heated houses into outdoor pens, each made for only a few pigs, are an unusual sight in a state where most pigs are produced in close confinement in expensive buildings housing 100 or more animals.

Tom Frantzen's farm in Iowa also looks different. Instead of fields planted uniformly with just corn or soybeans, strips only four rows wide, each planted with an alternating crop, wend their way across the land. And in contrast to most of the neighboring farms, which are rather devoid of wildlife, Delmar Akerlund's farm near Valley, Neb., has an abundance of earthworms, songbirds, and other wildlife. The earthworms are so plentiful that during a rainstorm they emerge from the soil and cover the roads adjacent to Akerlund's fields.

No reliable estimates have been made of the numbers of farmers using alternative methods. There is general agreement, however, that the movement is growing. One indication is that the membership of groups of farmers, such as the Nebraska Sustainable Agriculture Society, that practice alternative agriculture, is increasing each year, though each of them still has only a few hundred members.

In any event, farmers involved in alternative agriculture are gaining recognition in the agricultural policy community. Funds for research and extension programs in alternative methods have been appropriated by state legislatures in Illinois, Indiana, Minnesota, Iowa, Wisconsin, Texas, and California. Legislative provisions to enable more farmers to use alternative methods will be discussed this year when Congress debates the 1990 farm bill. USDA's Low Input Sustainable Agriculture program, funded at $4.5 million out of the department's $600 million research budget, is admittedly a small part of USDA's budget programs. But it is attracting a great deal of attention.

Certified Organic Farmers, a trade group, has been deluged with phone calls recently from farmers wanting to learn about organic methods. Several large fruit and vegetable growers in Kern County, California, stunned their competitors last year with a sudden decision to use organic techniques on part of their acreage. A spokesman from Certified Organic Farmers estimates that sales of organic produce doubled to $1 billion in 1988 from 1983.

Several factors occurring during the 1980s have pushed alternative agriculture to the forefront of public debate. First, farmers themselves became interested in it for a variety of reasons, including rising costs of purchased pesticides and fertilizers and growing concerns about the contamination of surface water and groundwater with pesticides and nitrogen fertilizers. Many of the farmers who have tried alternative methods have been very successful at them. The results have been clearly evident—rising yields per acre, fewer pesticide applications, and higher profits per unit of production.

In the past decade, the public also has become more aware of environmental and potential health problems associated with conventional farming. They have become concerned that surface and underground water supplies are being polluted with an increasing number of contaminants from agricultural production. They also became increasingly aware of pesticide residues in food. In February last year, this concern reached a high point with the publicity about a growth regulator, Alar, on apples and in apple products. In early 1990, antibiotic residues in milk also reached public consciousness. Alternative methods often markedly reduce the use of pesticides and synthetic fertilizers on crops, and antibiotics in livestock.

Contemporary agricultural problems

The development in the 20th century of the U.S. agricultural industry has been enormously successful from an economic perspective. In 1900, 37 out of 100 people in the U.S. made their living farming. They produced the

Benbrook: soil on much of U.S. cropland is compacted

food and fiber required for themselves and the other 63 out of 100 who made their living in commerce, industry, and other professions. Today only one out of 100 produces the agricultural goods required to support our society and to supply a large export market. This great increase in labor productivity is no accident. It is the result of generations of agricultural researchers, extension agents, industry representatives, government bureaucrats, political leaders, and farmers all working to build an increasingly sophisticated, large-scale agricultural infrastructure.

Wetlands have been drained and dry lands irrigated. Hundreds of insecticides have been developed and billions of pounds produced and dispersed over agricultural fields. Extensive use of herbicides has made weed control possible while conserving the use of tractor fuels in cultivation. Machinery to perform almost every task imaginable has been invented, much of it used in everyday farm operations. An amazing variety of chemicals is available to farmers, and vast tonnages are produced and applied annually. Agricultural researchers have developed improved seeds that require large amounts of fertilizer to obtain high yields. The American agricultural system has become the wonder and envy of much of the rest of the world.

Though modern conventional farming is highly successful in terms of total production and output per hour of human labor, it has troubling shortcomings when evaluated by other standards. Prominent among these are concern for human health and wildlife, the long-term sustainability of the resources that agriculture itself depends on, and the social and economic structures and viability of rural communities.

Even though 225,000 tons of pesticides are used annually on crops in the U.S., much of the crop yield is lost to pests, diseases, and weeds. According to David Pimentel, ecologist and entomologist at Cornell University, although the use of synthetic pesticides has shown a 33-fold increase since 1945, crop losses from insects, diseases, and weeds have increased from 31% in 1945 to 37% today.

In its 1989 report on alternative agriculture, NRC approaches the issue somewhat differently. Pesticides "have helped maintain pest damage at between 5 and 30% of potential production in many cropping situations, including highly uniform and often continuous monocultures that would otherwise be highly susceptible to severe pest damage," it states.

The interactions between farm management and pest pressure underlie the difficulty of assessing losses from pests. Establishing even a baseline for potential crop loss under various control methods depends on how the issue is approached. For example, corn grown continuously in the same field year after year is very susceptible to corn rootworm and therefore generally must be treated with insecticide incorporated in the soil, but if corn is grown in almost any type of rotation, corn rootworm is rarely a problem. It is hard to say whether insecticides for corn rootworm save a percentage of the crop, or simply allow corn to be grown as a continuous monoculture, as more than 30% of it is today.

As a result of efforts to control insects with insecticides, about 440 different insect and mite species and 70 fungus species have become resistant to some pesticides. Higher doses of the same pesticides or combinations of pesticides or substitution of different pesticides are necessary to control these resistant species. Also, broad-spectrum insecticides often kill the natural enemies of insect pests, thereby disrupting, rather than conserving, field ecosystems and allowing previously innocuous species to cause major crop damage.

Weed resistance, at first not believed to exist with herbicides, is also a problem. By 1989, about 80 out of a total of more than 500 weed species were found to be resistant to herbicides. Herbicides not only create resistance, they alter the mix of weeds that typically occur in an area. In Iowa, for instance, as some grassy weeds have been knocked out by herbicides, other kinds of broadleaf weeds, like velvetleaf, that are more difficult to control have come in to take their place.

About 20 years ago, shortly after herbicides were introduced, they nearly eliminated the need to cultivate for weeds. Now, because of weed resistance, farmers who use herbicides must still cultivate, though usually not as much so they would without them, says I. Garth Youngberg, executive director of the Institute for Alternative Agriculture.

Certain persistent herbicides used on some crops also make it impossible or difficult to grow certain other crops the next year. For example, if a farmer uses a persistent herbicide on a plot of land, he or she may not be able to get a good hay yield on that land the next year. Unfortunately, herbicide carryover and the development of genetic resistance are special problems with some of the highly effective, environmentally benign, low-dose sulfonylurea herbicides introduced in the past five years.

Pesticide contamination of both ground and surface waters from agricultural use has become increasingly prevalent in recent years. Some pesticides do not degrade very quickly and percolate through soils, especially sandy soils, into groundwater. Pesticides also can be carried attached to eroding soil particles and contaminate lakes, rivers, and estuaries.

In 1988, the Environmental Protection Agency (EPA) in a very incomplete survey detected 46 pesticides that could be attributed to normal agricultural use in the groundwater of 26 states. Most were detected below the health advisory level set by EPA, but nine were found at higher levels. The compounds found most frequently in groundwater were atrazine and aldicarb—the most acutely toxic registered pesticide. (Only 0.9 mg per kg body weight kills 50% of the test animals exposed to aldicarb.)

Another problem is that of pesticide residues on some foods. Even though the levels detected are very low, they have raised concern because herbicides accounting for 50%, fungicides accounting for 90%, and insecticides accounting for 30% of all agricultural use have been found to cause cancer in laboratory animals.

According to NRC, "pesticide residues in the average diet do not make a major contribution to the overall risk of cancer for humans," but the risk from pesticides "may not be insignificant." Fungicides are of particular

Groundwater of more than half the states contains pesticides from agricultural use

Pesticide	Health advisory level^a (ppb)	States	Median concentration^b (ppb)
Alachlor	1.5^c	Connecticut, Florida, Illinois, Iowa, Kansas, Louisiana, Massachusetts, Maine, Nebraska, Pennsylvania, Wisconsin	0.90
Aldicarb	10	California, Florida, Massachusetts, North Carolina, New York, Rhode Island, Wisconsin	9.00
Atrazine	3.0	California, Colorado, Connecticut, Illinois, Iowa, Kansas, Maryland, Maine, Nebraska, New Jersey, Pennsylvania, Vermont, Wisconsin	0.50
Bromacil	80	California, Florida	9.00
Carbofuran	36	Massachusetts, New York, Rhode Island	5.30
Chlordane	0.03^c	Mississippi	1.70
Chlorothalonil	1.5^c	Maine, New York	0.02
Cyanazine	9.0	Iowa, Louisiana, Maryland, Nebraska, Pennsylvania, Vermont	0.40
1,2-D	0.0013^c	California, Connecticut, Massachusetts, New York	4.50
1,3-D	0.20^c	New York	123.00
2,4-D	70	Connecticut, Mississippi	1.40
DCPA	3500	New York	109.00
Diazinon	0.63	Mississippi	162.00
Dibromochloropropane	0.02	Arizona, California	0.61
Dicamba	9.0	Connecticut, Maine	0.60
Dieldrin	0.00219^c	Nebraska, New Jersey	0.02
Dinoseb	7.0	Massachusetts, Maine, New York	0.70
Diuron	14	California	na
Ethylene dibromide	0.0005^c	California, Connecticut, Georgia, Massachusetts, New York, Washington	0.90
Fonofos	14	Iowa, Nebraska	0.10
Hexazinone	210	Maine	8.00
Lindane	0.026^c	Mississippi, New Jersey, South Carolina	0.10
Methyl parathion	2.0	Mississippi	88.40
Metolachlor	10	Connecticut, Illinois, Iowa, Pennsylvania, Wisconsin	0.40
Metribuzin	175	Illinois, Iowa, Kansas, Wisconsin	0.60
Oxamyl	175	Massachusetts, New York, Rhode Island	4.30
Picloram	490	Maine, North Dakota, Wisconsin	1.40
Prometon	100	Texas	16.60
Propazine	14	Nebraska, Pennsylvania	0.20
Simazine	35	California, Connecticut, Maryland, Nebraska, New Jersey, Pennsylvania, Vermont	0.30
TDE	0.031	Mississippi	4.80
Trifluralin	2.0	Kansas, Maryland, Mississippi, Nebraska	0.40

a Lifetime health advisory level proposed by Environmental Protection Agency. b Median of the concentration of positive detections for all confirmed studies. If multiple studies were not done on a particular chemical, the single-study average is given. c Carcinogen. EPA proposed lifetime healthy advisory level is based on the exposure levels that present a one in a million risk of cancer in the exposed population. na = not available. Source: Environmental Protection Agency

concern because they are used in combinations and "few effective alternatives are available or under development." NRC points out that synergistic effects may result from residues of more than one pesticide.

However, a new study carried out by Fermenta ASC found that residues of the fungicide chlorothalonil were reduced considerably as celery, cabbage, tomatoes, and cucumbers moved from farm to table. In some of these vegetables, washing, grading, trimming, packaging, and cooling lowered residue levels by more than a factor of 10.

Some pesticides seem to pose a health threat for farmers who use them frequently. The National Cancer Institute found in a study of farm workers that those who are exposed to herbicides for more than 20 days each year are six times more likely than the average person to develop non-Hodgkin's lymphoma. In a followup study, NCI found a threefold increase in risk for the same disease in farm workers who used 2,4-dichlorophenoxy acetic acid (2,4-D) more than 20 days per year.

Pesticide use has also stressed wildlife populations and decimated large wild and domestic honeybee populations. Bees are important for farmers because they are necessary for pollinating about $20 billion worth of fruits, vegetables, and forage crops.

Agriculture is the largest diffuse source of water pollution in most states. Large amounts of nutrients applied as fertilizer are absolutely essential to the productivity of U.S. agriculture. But the major pollutant from farmland in most cropping regions is fertilizer runoff.

Nutrients have several different types of adverse environmental impacts. First, nitrate from all sources—synthetic fertilizers, manure, and green manures (legumes)—is soluble in rainwater and, if not used by plants, leaches through the soil to contaminate groundwater or surface water. There is evidence that nitrate contamination of groundwater supplies is increasing. A U.S. Geological Survey study found nitrate levels in 87 of 1663 counties above 10 mg per L—EPA's interim standard for nitrate in drinking water. Extensive exposure to nitrate levels above 10 mg per L can lead to methemoglobinemia (oxygen deficiency in the blood), particularly in nursing infants and in the elderly.

Unlike nitrate, excess phosphorus from fertilizer is not very soluble, but it is carried on eroding soil particles to streams, lakes, and estuaries. Both nitrate and phosphorus, but especially phosphorus, promote abundant growth of algae, which, when it dies, decays on the bottom of water bodies, depleting the oxygen in the water. As a result, dissolved oxygen is less available for higher order aquatic plants and animals.

There is a great deal of evidence that nitrogen fertilizers are being overapplied. Alfred M. Blackmer, agronomist at Iowa State University, says that probably more than half of the nitrogen put on the soils in the corn belt is not taken up by crops. "It is likely that a substantial portion of this nitrogen finds its way into groundwater supplies," he says.

In regions of the country where livestock production results in the need for disposal of large volumes of manure on agricultural fields, the situation is aggravated still further by farmers' common practice of applying synthetic fertilizers at the same rate that would be required without manure, says Charles M. Benbrook, executive director of NRC's Board on Agriculture. In some midwestern cropping-livestock areas, researchers have found fields with more than 10 times the level of available nitrogen needed to support maximum yields.

Phosphorus fertilizer is also being overused as is pointed out in the NRC report. "Most state soil test labs report that the number of farm fields testing high or very high in phosphorus increased dramatically from the 1950s to the 1980s," says Raymond R. Weil, agronomist at the University of Maryland. Problems with overuse of fertilizers could be eliminated fairly easily by more precise application methods and with greater use of soil tests.

Erosion depletes topsoil, increasing the need for fertilizer. Eventually erosion makes land totally unproductive. It also causes siltation of streams, lakes, and reservoirs and excessive turbidity in surface waters. This, in turn, blocks out light, resulting in the decline of submerged aquatic vegetation. Because nutrients and some pesticides are carried on soil particles, erosion also contaminates surface waters.

Agricultural specialists differ greatly in their assessments of how serious the erosion problem is in the U.S. Benbrook says erosion is still a serious problem on only about 20 million to 30 million acres of U.S. farmland, out of a total of about 400 million acres, as a result of the effectiveness of erosion control provisions in the 1985 farm bill (the Food Security Act of 1985)—especially the conservation reserve program.

Pimentel's view is less sanguine. Erosion on average is proceeding at 20 times the rate of replenishment, he claims. For example, in Iowa, half the topsoil has been lost in the past 150 years.

Wes Jackson, geneticist and head of the Land Institute in Salina, Kan., a think tank devoted to sustainable agriculture, shares Pimentel's concern. On anything but dead-level cropland, soil losses from erosion are usually too high to be sustainable in the long run, he notes.

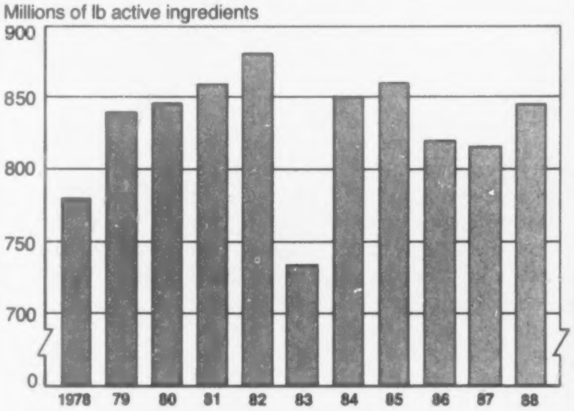
According to Benbrook, on flat, generally richer soils not subject to heavy erosion, compaction is one of the more serious problems that results from conventional farming practices. Soil on much of the nation's cropland—perhaps half the intensively cultivated row-crop and small grain acreage, in Benbrook's view—is becoming, or already is, compacted. As a result, this soil fails to take in and hold precious water as effectively as soils with more tilth. Compaction is caused by growing shallow-rooted crops year after year, by not incorporating enough organic matter into the soil, by practices that alter soil microbial and earthworm populations, and by using heavy machinery, particularly on wet soils. Compacted soil, when dry, looks like brick. It restricts root growth and has soil oxygen levels below those necessary for optimum uptake of nutrients.

Compacted soil can be restored by planting deep-rooted crops, such as alfalfa, incorporating organic materials like green manure and animal wastes, or using a subsoil tiller. But tillage equipment is heavy and requires a great deal of fuel to pull through tightly bound soils. Moreover, subsoil tillage must be timed very carefully. If the soil is too dry or too wet, subsoil tillage merely makes the problem worse.

Probably the most hard-to-solve natural resource problem associated with conventional agriculture is the depletion of aquifers. The Great Plains, which encompass one fifth of the land area of the contiguous 48 states, are running out of water very quickly. The Ogallala aquifer, the main source of irrigation water on the plains, is being pumped out 20 times faster than it is recharging itself, and at the present rate, irrigation from the aquifer can last only a half-century, says Richard Black, an irrigation specialist at Kansas State University. Under parts of the Texas panhandle where the formation is thinner, the aquifer has already become so depleted that many farms have reverted to dryland farming.

Cases of salmonella food poisoning in the U.S. have escalated in recent years. Reported incidence rose from

Agricultural use of pesticides has declined slightly since early 1980s



Note: Excludes wood preservatives, disinfectants, and sulfur.
Source: Environmental Protection Agency

about 3 per 100,000 people in 1955 to 20 per 100,000 in 1987. Some experts believe that a significant part of the increase can be attributed to changes in animal husbandry requiring the use of antibiotics in animal feed. The use of antibiotics, now 9.9 million lb annually, has risen as more and more farm animals are raised confined in large buildings where they live in close proximity to each other. Because animals raised in this way have greater risk of respiratory and other diseases, small amounts of antibiotics are added to their feed. The antibiotics also promote growth.

Last year, the Institute of Medicine at NRC reported that though there is little direct evidence of a link between the subtherapeutic use of antimicrobials in livestock and human disease, there is substantial circumstantial evidence of such a link. Daily use of antibiotics causes resistant salmonella to develop in livestock. Since the same antibiotics are also used in humans, human disease caused by salmonella sometimes resists treatment. The institute conservatively estimated that salmonella from the use of subtherapeutic antimicrobials causes about 40 deaths per year.

A number of economic problems plague modern U.S. agriculture. First, about a quarter of the farms owned by individuals went out of business during the 1980s. Many were caught in a debt squeeze as commodity and land prices fell while prices of fuel, fertilizers, herbicides, and seed rose through 1984.

The number of lost farms would have been even greater if federal farm support programs had not escalated from $3.5 billion in 1978 to a peak of $26 billion in 1986 and remained fairly high, at about $11 billion, in 1989.

Despite the high cost of federal support programs, net farm income including federal payments has risen only slightly in real purchasing power since 1970. And even now, about 19% of all farms are financially shaky. Many operators have taken second jobs, not because they spend less than eight hours a day on the farm, but because that is the only way they can afford to keep their farms.

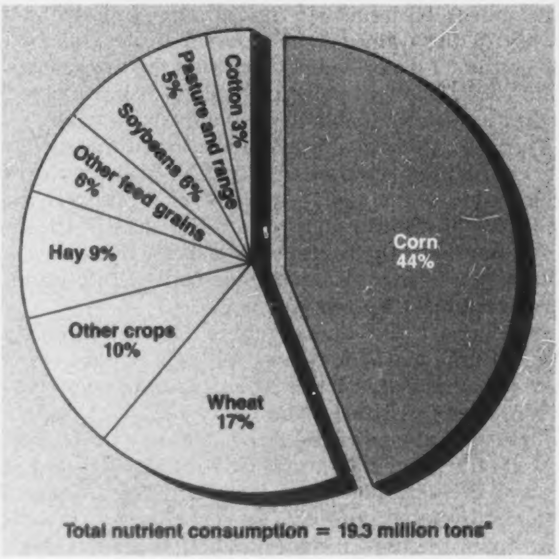
Alternative farming methods

Alternative agriculture originated with farmers who became dissatisfied with the performance of conventional farming systems. Most of them are in New England, the Midwest, California, and Texas, though there are a number in every state.

Some, like Frederick Kirschenmann in North Dakota, found that their soil seemed harder and harder to plow each year and required more and more fertilizer to produce the same yield. Some saw their insect control practices failing despite their increasing use of insecticide. Some simply found they were making little or no money each year because their input costs were going up while their gross sales were remaining steady or declining.

A number of these farmers managed to work out systems that seemed to them more sustainable over the long run and in many cases just as productive. Some of them carried on extensive experiments on their own farms to find alternative systems that worked best.

Corn accounts for nearly half of U.S. fertilizer consumption



Total nutrient consumption = 19.3 million tons[a]

[a] For year ending June 30, 1989. **Sources:** Doane, Department of Agriculture

Many novel ideas were tried and rejected as ineffective or impractical. Eventually though, several farmers who had worked out successful new systems became known to the agricultural research establishment. The establishment—the cooperative extension service at Iowa State University, for example—then began to take notice, participating even in direct research on such farms.

When NRC first began to investigate alternative farming in 1984, many of its committee members were skeptical about the success of these farms, Benbrook recalls. They found it hard to believe that some farms could produce crops well with little or no pesticides or that some could raise animals profitably without subtherapeutic use of antibiotics. They speculated that such farms must have some unusual characteristics—perhaps better soil, lots of available labor, or some other distinct attributes—that enabled them to do things differently.

But when the committee members learned more about the farms, they found that they were typical in most respects, though managed in an unconventional way.

Not enough research has been done on any of the alternative systems that farmers have developed to know whether they are sustainable in the long run. Nor can the systems simply be copied on farms across the U.S. Conditions vary greatly and so must farming systems; further research is clearly needed. However, a number of the methods used are based on accepted scientific principles and a wealth of empirical evidence.

There has not been enough experimentation with alternative systems to discuss them in the aggregate. For example, it is not possible to say: "out of 1000 farms using the new ridge-tillage system, 750 had better yields," because research trials have not been done on 1000 farms. As a consequence, specific farms must often be used to illustrate alternative systems, just as case studies are often used in medicine and business administration to indicate, but not prove, the results from certain practices.

One of the most common methods used in alternative farming is increased crop rotations, especially rotations over more than two years. Rotations help control insects and diseases, particularly those that attack roots, by eliminating the food of the disease or pest and thus often preventing destructive levels of pests or disease organisms from becoming established.

For example, damage from wheat root pathogens in Washington state can be greatly decreased with two-year rotations with peas and virtually eliminated with three-year rotations with barley and peas or lentils.

Even when grain follows a nonleguminous crop and therefore does not benefit from nitrogen supplied by a legume, rotations also increase yield for reasons not entirely understood. And grain yields following a legume are usually greater than yields of grain planted as a continuous monoculture, no matter how much fertilizer is applied.

Rotations, especially sod-based ones, add organic material to the soil, increasing its water holding capacity, reducing compaction, and providing food for soil organisms that recycle soil nutrients.

Deep-rooted crops, such as alfalfa, used in rotations bring soil nutrients to the surface and make them available for shallow-rooted crops. They also help prevent soil compaction by forming deep root channels.

Rotations also can help control erosion, especially if hay or forage crops or closely seeded grain crops are planted in strips that follow the contour of the land. Rotations that include crops, such as rye, that are allelopathic to weeds aid in weed control. (Allelopathic plants contain chemicals that suppress growth of other plants.) Some farmers who plant rye one year find that they need little or no herbicide the next year.

Usually, farms with rotations have different fields or different strips planted in a variety of crops. Because a severe insect attack or disease usually attacks only one crop in a given year, crop rotation reduces the likelihood that all the crops will fail. However, rotations that include hay and forages are probably not economical for farms without livestock or a developed hay market.

A number of methods to maintain soil fertility, while at the same time reducing the amount of purchased fertilizer, are being used in alternative farming systems. Some of these techniques are saving farmers substantial amounts of money, even in the first year they are used.

One practice involves the more careful and precise management of the primary plant nutrients. Farmers in Iowa are using a new soil test for nitrogen that gauges the amount the crop needs precisely. Soil tests for potassium and phosphorus and a soil test for nitrogen for semiarid climates have been available for many years. But a test for nitrogen for regions where there is adequate rainfall was developed only recently. Farmers can use a kit and analyze their soil samples themselves in just a few hours. The kit is based on cadmium reduction of nitrate to nitrite and colorimetric determination of nitrite. The test allows farmers to estimate more precisely, when the plants are 6- to 12-inches high, the minimum amount of nitrogen fertilizer needed for maximum yield.

Fifty-eight on-farm trials comparing the conventional fertilizer practice with the new practice involving the soil test have been coordinated by the extension service at Iowa State and by agronomist Blackmer in cooperation with fertilizer dealers. In both sets of trials, the yields on fields with the reduced application of nitrogen recommended by the soil test were the same as the yields on fields where fertilizer was applied in conventional amounts.

Blackmer estimates, over the long run, Iowa farmers who use the new soil test will need about a third less fertilizer than they used in the past. Just in Iowa, "that could mean an annual saving of $100 million at current prices," he says. Similar nitrogen soil tests have been used successfully by farmers in Wisconsin, Vermont, Pennsylvania, and Connecticut.

Triazine herbicides detected in streams in 10 midwestern states

Detectable levels of triazine herbicides exist in more than half the streams in the midwestern U.S., according to a new U.S. Geological Survey (USGS) study.

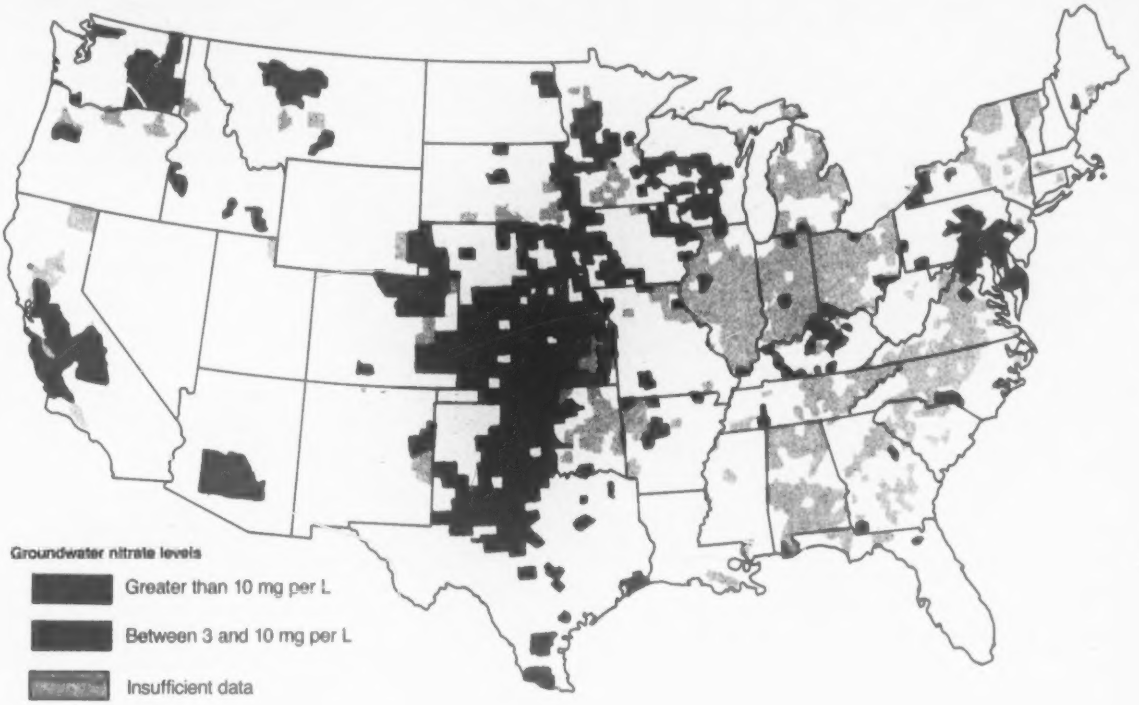
Last year, in the early spring before herbicides were sprayed on the fields, USGS hydrologists sampled 150 streams over an 80,000-square-mile area in 10 midwestern states and found triazine herbicides in 55% of them. A sampling later in the spring, after herbicides had been used on the fields, detected herbicides in 90% of the streams. A new enzyme-based immunoassay, which is cheaper and much faster than the usual gas chromatography/mass spectrometry method, was used to identify the presence of the triazine compounds.

When samples collected in the later survey were analyzed further, 34% were found to exceed the proposed Environmental Protection Agency standard for alachlor in drinking water (1.5 ppb), 55% exceeded the standard for atrazine (3.0 ppb), 12% exceeded the standard for cyanazine (9.0 ppb), and 4% exceeded the standard for simazine (35 ppb).

Because some of the sampled streams are drinking water sources, Donald A. Goolsby, USGS water quality specialist for the central U.S., expects to find detectable levels of triazine herbicides in a number of drinking water supplies, too.

About 60% of the pesticides used in the U.S. are applied to crops in the 10 midwestern states where streams were surveyed. USGS plans to do more extensive tests this year.

Most agricultural counties with high groundwater nitrate levels are west of the Mississippi



Note: Environmental Protection Agency standard is 10 mg per L. **Sources:** Department of Agriculture, U.S. Geological Survey

Farmers are also making greater use of manure and forage legumes as a source of nutrients. Many raise livestock to have a source of manure as well as an economical use for hay and forage crops grown in rotations. In humid areas, forage legumes often can provide all or nearly all the nitrogen needed by a crop grown the next year. In semiarid climates, however, such legumes tend to take so much moisture out of the soil that subsequent crop growth is retarded.

A variety of tillage practices are being used in alternative farming to control weeds, pests, erosion, and plant nutrients. There is no single tillage practice that will work on all soils and in all climates. But a tillage system that may have advantages in many different types of soils is ridge tillage as developed by Iowa farmer Richard Thompson.

Ridge tillage itself was first used in China more than 3000 years ago. In modern times, it was used in Nebraska and then in Texas and Arizona for growing cotton. It is a form of reduced tillage that entails planting a crop on the top of ridges, leaving the residue from the previous year's crop largely undisturbed. The soil is not worked ahead of time to prepare a seed bed. On most farms, herbicides are applied in a band over the ridges at the time the seeds are planted.

Ridge-tillage systems are effective in controlling water and wind erosion. If the ridges are laid out on the contour, each ridge can act like a small terrace, and soil that blows off the tops of the ridges tends to collect in the valleys. Erosion is also slowed because crop residues are left on and between the ridges.

Another advantage is the soil on ridges dries out and warms up earlier in the spring so planting can begin earlier. After the crop has come up, ridge tillage also allows for more efficient use of fertilizer because it can be placed along the sides of the rows where it is accessible to crop roots. There is no tilling at the time of planting to disturb weed seeds so ridges help with weed control.

Thompson has modified the conventional ridge-tillage system so that no herbicides are needed. For the past three years, Iowa State's extension service has been conducting trials on Iowa farms that are testing Thompson's method. These trials have not shown any significant differences in yields on ridges with and without herbicides.

Another practice being used in alternative agriculture is to control weeds by shallow cultivation that disturbs soil structure only minimally rather than by using herbicides. Cultivation, like any farming practice, can create more problems than it solves. Done inappropriately on highly erodible cropland, it can add to soil erosion and water quality problems, though it causes much less erosion than fall or spring plowing.

On land growing fruits and vegetables, a number of

Chemical elements essential for growth, development, and maturation of crops

Essential chemical element	Form used by crop	Source
Carbon	CO_2	Air
Oxygen	CO_2	Air
Hydrogen	H_2O	Soil water-rainfall, irrigation
Nitrogen	NO_3^-, NH_4^+, N_2	Soil organic matter, animal manures, fertilizers, air (legume crops)
Phosphorus	$H_2PO_4^-$, HPO_4^{2-}	Soil organic matter, soil minerals, fertilizers, animal manures
Potassium	K^+	Soil minerals, animal manures, plant residues, fertilizers
Calcium	Ca^{2+}	Soil minerals, limestone, fertilizers
Magnesium	Mg^{2+}	Soil minerals, dolomitic limestone, fertilizers
Sulfur	SO_4^{2-}, SO_2	Soil organic matter, animal manures, SO_2 in air, fertilizers
Boron	H_3BO_3	Soil minerals, fertilizers
Chlorine	Cl^-	Rainfall, soil, fertilizers, animal manures
Copper	Cu^{2+}	Soil minerals, animal manures, fertilizers
Iron	Fe^{2+}	Soil minerals, fertilizers
Manganese	Mn^{2+}	Soil minerals, fertilizers
Molybdenum	MoO_4^{2-}	Soil minerals, fertilizers
Zinc	Zn^{2+}	Soil minerals, animal manures, fertilizers

In addition to nitrogen, phosphorus, and potassium, many other elements—calcium, magnesium, sulfur, boron, chlorine, copper, iron, manganese, molybdenum, and zinc—are needed by crops in much smaller quantities. Most of these minor nutrients can be supplied by soil minerals, manure, fertilizers, and plant residues.

Nutrients removed from the soil must eventually be returned if healthy crops are to be grown indefinitely. By combining crop rotations, including legumes (which fix nitrogen from the air), with manure from livestock, farms can be self-sufficient in nitrate and potassium. But over the long run it appears difficult or impossible for them to be self-sufficient in phosphorus.

In addition to the major nutrients it supplies, manure that is treated properly provides organic matter, increases soil's ability to absorb and hold water, and supplies food for microorganisms. Also, manure often releases nitrate at a rate that closely approximates plant needs. Because the nitrate in synthetic fertilizer tends to be more soluble, much of it may leach out of the soil before crops can take full advantage of it, especially if all the fertilizer is applied at one time.

Advocates of alternative farming emphasize the importance of using manure and legumes as major sources of nutrients. But not enough livestock are currently raised in the U.S. to supply crops' nutrient needs. The Department of Agriculture estimates that manure could supply only 15% of the total nitrogen, 10% of the phosphorus, and 24% of the potassium used on all crops now grown in the U.S. However, Alfred M. Blackmer, an agronomist at Iowa State University, believes that these estimates are too low.

Currently, much manure is wasted because it is produced in concentrated amounts in large livestock operations, such as poultry farms and cattle feedlots, many of which are located far from cropland. Instead of a resource, such manure often is an environmental hazard that pollutes water supplies with nitrate.

One underutilized source of nutrients is sewage sludge. Much of the sludge now generated in the U.S. has such high concentrations of heavy metals, however, that it cannot be used indefinitely on cropland. But if all municipalities were to comply with Environmental Protection Agency regulations, most of their sewage sludge could be spread safely on cropland, says Alan B. Rubin, chief of EPA's wastewater solids criteria branch.

alternative farmers are planting grass or another cover crop between rows to control weeds and erosion and to create a habitat for beneficial predator insects. The large vineyards in Arizona and California owned by Steven Pavich & Sons, which produce more than 1% of the grapes in the U.S., have a permanent cover of perennial rye grass between the vines.

Pest control

Alternative agriculture controls pests by maintaining soil fertility, rotating crops, and using integrated pest management, biological controls, and natural products like rotenone. The area of pest control seems to be one of the most complex and diverse, and hence least well understood. Alternative methods developed thus far are highly variable depending on the region of the U.S. In Florida's hot, humid climate, for example, pest pressures are typically very high, so few growers have been able to control insects and diseases without insecticides and fungicides. In the hot, dry climate in California, alternative control techniques are much easier to design.

Some farmers, such as Thompson in Iowa, find that rotating crops, using ridge tillage, and providing a high degree of soil fertility prevent significant yield losses from pests. Even when his soybean fields were surrounded by spider-mite-infested fields in 1988 and other farmers in his area found it necessary to spray for spider mites, Thompson's fields remained largely untouched.

In the Pavich grape vineyards, insects are seldom controlled with insecticides. Usually grapes on conventional California farms are sprayed four to six times a year. Even when the vineyards surrounding the Pavich vineyards in California are heavily infested with spider mites, the Paviches ordinarily spray only a small part of their grapes once a year.

The Paviches believe that careful balance of nutrients in the soil and careful pruning and care of the vines, as well as growing rye between the rows to provide a habitat for insect predators, help control pests. However, like all other grape growers, the Paviches have to fumigate the ground for nematode control before the vines are planted.

Integrated pest management, developed about 20 years ago and long used by some farmers, especially on cotton, is a pest control strategy based on determining when a pest population is approaching the level at which control is necessary to prevent a decline in net returns.

It does not always reduce pesticide sprayings over what would be done on conventional farms. In fact, in some cases it increases the number. But it does usually decrease the total amount of insecticide used.

There are a number of biological pest controls employed in alternative farming, including release of nonnative natural predator pests, augmentation of domestic natural pest enemies, release of sterilized insect pests, and use of insect pheromones to disrupt their mating.

Many farmers who grow organic vegetables use *Bacillus thuringiensis* (Bt) as an insecticide. It is a species of bacterium found in soil. Each variety of Bt used as an insecticide contains one or more crystalline proteins that kill a specific kind of insect and are harmless to all others and to humans and the environment.

Farmers are developing alternative methods of livestock production to accomplish several goals: eliminate the use of subtherapeutic antibiotics in livestock, eliminate the use of growth hormones, produce animals without investing in large, expensive facilities, and still make a profit.

There is much evidence that high-confinement facilities, such as buildings housing hundreds of hogs, lead to more stress on the animals and hence to more diseases, than would be present if the animals were raised in a less confined environment. Therefore, farmers are designing low- and medium-confinement systems such as pastures with plenty of room for each animal or low-confinement hutch and yard facilities.

A number of farmers are experimenting with what is called intensive rotational grazing, allowing animals to graze a certain pasture only as long as the nutritive value remains high and then moving them onto another field so the first can recover. It requires more labor and more fencing than most pasture systems. For example, Clark BreDahl in southwestern Iowa uses a system of fences and crossfences so that he can turn his cattle and sheep into any of his fields to consume crop residues. Each field or section of field can be grazed for the optimum amount of time.

Economic performance

In general, farmers that have made it through the often difficult transition period when a range of practices are tried out, settle on alternative methods that perform as well or better financially than conventional methods in their area. It is very hard to make detailed comparisons because the performance of diversified, biologically based systems arises from a complex array of interactive factors. Simple input-output analysis is just not feasible. Also, farms using these systems tend to differ greatly, because cropping patterns and practices must be matched to the individual strengths and limitations of each farm's natural resources.

But yields on farms with successfully refined alternative practices are usually just as high or higher than county averages. In animal production, the situation is similar. Animals raised with little or no antibiotics in their feed and in low-confinement facilities seem to be just as productive or more so than those raised with antibiotics in high-confinement operations.

There are some exceptions, however. The organic rice operation owned by Lundberg Family Farms in northern California has yields that are consistently lower than the average for conventional rice production. High-yield methods to provide adequate nitrogen and eliminate herbicides and pesticides in rice production have not been developed.

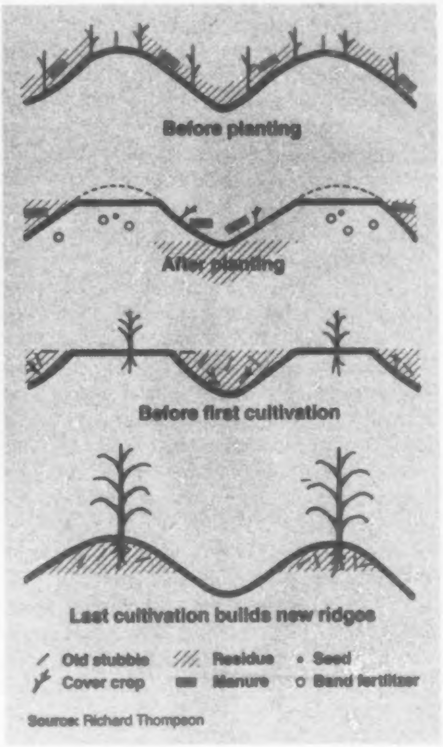
The BreDahl farm illustrates the beneficial effect that low expenses for purchased inputs can have on profits. At 160 acres, it is half the size of the average farm in its county. Detailed financial comparisons have not been made, but local tax experts are convinced the farm ranks in the bottom 25% for the area in gross sales, but in the top 10% in net income.

Currently, it is difficult or impossible for most farmers to move toward alternative farming systems, and in most cases, there has so far been little incentive. Both the federal commodity programs and a lack of information about alternative methods are roadblocks to change. And for many farmers, the conventional methods recommended by extension agents, based on decades of work by agricultural researchers at universities and in industry, have been effective, convenient, and economical.

Under existing law, farmers lose benefits if they rotate crops or respond to market forces by switching to other crops. Crops eligible for price and income supports include feed grains, wheat, cotton, rice, soybeans, and sugar. If farmers' base acres are enrolled for one of these crops, and they reduce their acreage when they rotate to another unenrolled crop, they reduce their potential payments in future years. Also, if the yield of an enrolled commodity crop declines, even for just a year or two, deficiency payments in future years are reduced.

Little information about alternative systems is available to farmers in most states. The information county extension agents supply is largely prescriptive. Except in a few states that provide guidance about integrated pest management, extension agents' handbooks contain mostly chemical methods for controlling weeds and insects, which are listed in tables. For each weed is listed an herbicide (or several herbicides) and its effective application rate. Usually, handbooks contain only one sentence on any other method of managing weeds: "Cultivation can be used to control weeds." The handbooks include similar information for insects—listings of insects and insecticides with application rates. Typically, tillage practices, planting times, crop rotations, allelopathic effects, planting densities, nutrient balance, or other methods that could be used to control weeds or insects are not mentioned.

Dept. of Agriculture photo



Source: Richard Thompson

Ridge tillage often eliminates herbicide use

Ridge tillage, as developed by Iowa farmer Richard Thompson, almost totally eliminates the need for herbicides. First, a planter shaves off 2 to 4 inches of soil in a 6-inch band from the top of ridges remaining from the previous growing season, throwing cover crop, weed seeds, weeds, and soil into the furrows between the ridges. This helps mix manure, which is applied just ahead of the planter (shown in photograph), with the soil and creates a planting strip that is unoxygenated and mostly free of weeds and weed seeds. Three stimulants for weed germination—oxygen, light, and warm temperature—therefore have not been present in the planting strip. Compared with most farms, fast-emerging varieties of corn and soybeans are planted more densely and fertilizer is added. The new plants quickly establish a small shade canopy that provides weed control within the rows. Early weeds are eliminated with a rotary hoe. During the early part of the growing season, crops are cultivated three times. At the last cultivation, the ridges are rebuilt and, in September, a cover crop is planted to control erosion, retain soil nitrogen, and choke out weeds that might germinate later. Thompson claims his method requires more labor than no-till farming with herbicides but less labor than conventional farming with herbicides as practiced on most Iowa farms.

Research needs

Much more research needs to be done before alternative systems are available for all crops in all regions of the U.S. Specialists involved in agricultural research say the major thrust of research in the area must focus on how different organisms interact in overall farming systems rather than on narrow isolated problems or the impacts of specific inputs, as in the past. Interdisciplinary research is needed to study the interactions between various components of a farming system and the biological and ecological foundations of farming systems that are both profitable in the near-term and sustainable over many years.

Specialists also agree not enough is known about existing alternative techniques to determine whether they are truly sustainable in the long run. They stress that on-farm research is important for developing alternative systems. It involves the farmer so it tends to address questions that he or she needs to have answered. Often in the past, a new agricultural technique appeared to fail simply because the person taking care of the research plots at the experimental station didn't know how to manage that technique. If farmers with highly developed skills are taking care of the plots, this is less likely to happen. Also, when research is carried out on a farm, the results are more accessible and perhaps more credible to other farmers.

The National Soil Tilth Laboratory in Ames, Iowa, is being organized to study overall farming systems. "What the soil tilth lab will be doing is looking at interactions between chemical, physical, and biological systems at all levels," says Jerry L. Hatfield, director of the lab. "Others looked at these individually. We are setting up our research so it is multidisciplinary at the outset."

Some areas of alternative agriculture that especially need more research are low-cost low-confinement facilities for livestock, less toxic replacements for fungicides or practices that will eliminate or reduce the need for fungicides, and development of systems of growing vegetables and fruits in hot, humid areas without

Alternative agriculture on small versus large farms

"A long-term transformation is underway in American agriculture from small-scale, broad-based family farming to large-scale industrial farming," says Marty Strange, program director of the Center for Rural Affairs, an advocacy group in Walthill, Neb., for low-income farmers and other rural people.

The total number of farms in the U.S. dropped from about 5.9 million in 1945 to 2.2 million in 1985. Now, the largest 4% produce about half the food, and 400 superfarms produce a sixth of the nation's food—more than all the farms in Iowa, Illinois, and Florida together.

With the decline in the number of farms has come the depopulation of rural communities. For example, rural counties in Iowa, Kansas, North Dakota, South Dakota, Minnesota, and Nebraska have lost on average 6% of their population since 1969, while the total population of these states has risen 8%. North Dakota has had to initiate a triage policy, letting some communities die while giving economic aid to others. State officials in North Dakota say there isn't enough money to maintain services in all the communities, and there is little hope of attracting new businesses to all of them, so they try to save a few that seem to offer the most hope of sustaining a viable economy.

Some applaud the changes that are taking place. It is good that fewer people can produce more food than ever before, they say. And even if it is not good, it is inevitable. Food can be produced most efficiently and cheaply on very large farms, they allege.

But others, like Chuck Hassebrook, policy analyst at the Center for Rural Affairs, view the situation as neither positive nor inevitable. As the farms in an area become larger and larger, the communities in those areas become less desirable, Hassebrook says. "A substantial body of research indicates that farm communities in which land is widely held are more prosperous than those with concentrated land ownership in nearly every respect, including lower poverty rates and a greater variety and larger number of local businesses, churches, schools, community organizations, and public services," he explains.

Dean MacCannell of the University of California, Davis, has studied the relationship between farm size and economic and social structure of rural communities. "Communities that are surrounded by farms that are larger than can be operated by a family unit have a few wealthy elites, a majority of poor laborers, and virtually no middle class. The absence of a middle class at the community level has a serious negative effect on both the quality and quantity of social and commercial services, public educa-

heavy use of pesticides or with use of less toxic pesticides.

Farm bill proposals

A number of the legislative proposals for the 1990 farm bill will, if enacted, benefit alternative agriculture. Nearly all of those addressing agricultural commodity programs aim to give the farmer more flexibility in deciding which crops to plant. All sides in the current debate over the farm bill, even those who disparage alternative agriculture, believe the existing farm program rules are too restrictive and reward farmers for practices that make little sense agronomically or environmentally.

The Administration proposal announced Feb. 6 by Agriculture Secretary Clayton K. Yeutter would allow farmers to plant alternative crops without losing government benefits.

Basically, the Administration bill would use what it calls "positive incentives" to reduce soil erosion, groundwater contamination, and other environmental problems and it emphasizes the need for more research and education.

Another proposal, also announced Feb. 6, by a coalition of environmental groups and supported at least in part by several Congressmen, takes more of a regulatory and activistic approach. The most extreme proposed regulation would require that farmers keep records of pesticide and nutrient use and develop plans to reduce their use. In areas where water quality is a problem, farmers would be required to develop plans by 1995 to reduce the use of potential pollutants and to implement these plans by 2000.

Yeutter is opposed to this regulation. He believes that it will antagonize farmers.

To reward farmers who adopt sustainable practices, the coalition supports incentives for rotations, for planting cover crops, and for adopting practices that protect water quality. It also wants food grading standards changed to eliminate the emphasis on cosmetic appearance of fruits and vegetables. A large fraction of pesticides are now used solely to ensure that foods will measure up cosmetically, even when processed into sauces or juices. In addition, the coalition asks that strong uniform federal standards be set up for organic farming to promote its use. Currently, 15 states have regulations—each different—governing organic farming.

The Sustainable Agriculture Working Group, a network of midwestern alternative agriculture and environmental organizations, has pro-

C&EN staff photo

Carpenter: NRC report not a prescription for every farm tion, and local governments," MacCannell says. He describes such communities as neofeudal and structurally similar to those in the Third World.

Most U.S. government agricultural policies have helped large farms more than small and mid-size ones, Strange says. Therefore, if a conscious effort is made to change these policies to aid smaller farms or to at least create a level playing field, the trend toward larger and larger farms can be reversed, he argues. Even the agricultural research projects that the Department of Agriculture chooses to fund are a form of social planning, he adds. Some projects, like the development of an apple-picking robot costing $160,000, can help only very large farms. Therefore, choosing projects that are relevant only to large farms is one more force aiding their growth and taking research money from projects that might benefit smaller farms.

Robert E. Barrow, Master (head) of the National Grange, holds similar views. He says that the very commodity policies, tax laws, trade, and foreign and fiscal policies that the Grange supported for many years have created "an agricultural production machine that has consumed farmers. . . . Our emphasis has been on production rather than people. Yet, there is compelling evidence that, from the perspective of rural development, it is time to reexamine the questions of farm structure."

To counteract the trend toward larger farms, eight midwestern states have passed laws that make it illegal for corporations to purchase any more farmland.

Hassebrook believes alternative farming methods could help small and mid-size farms by reducing their need for purchased supplies and thus enabling more of them to stay in business. This could help reverse the trend toward larger and larger farms, he says.

Hassebrook also thinks that sustainable systems are more likely to be used and to succeed on mid-size or small farms because alternative farming requires highly developed management skills.

Charles M. Benbrook, executive director of the Board on Agriculture at the National Research Council, agrees that if alternative agriculture is to succeed on a broad scale, the trend toward larger and larger farms will have to be reversed, though he acknowledges that alternative methods have been used on some very large farms.

Because of this reciprocal relationship between smaller farms and alternative agriculture, a number of groups who are interested in helping family farms and strengthening rural communities are also interested in promoting alternative agriculture.

posed legislation that would remove existing penalties in commodity programs and reform federal farm programs so that they would reward farmers for preserving and improving soil and water resources. The working group's approach is broader than that of the environmental coalition. The coalition's proposals focus on specific areas of the U.S. with acute pollution problems from farming practices, by paying farmers who are causing particular problems to change. The working group's proposals would reward careful stewardship of the land across the board, including those farmers who have been practicing alternative agriculture all along. They also would reorient publicly funded agricultural research toward alternative methods.

Reactions

For the most part, chemical company spokesmen express a favorable attitude toward alternative agriculture. They recognize that some serious problems are associated with conventional agriculture. "In most cases if we are really going to protect soil and water, the move to sustainable methods will be a very positive thing," says Will D. Carpenter, vice president for technology at Monsanto Agricultural. "Those of us who have been in agricultural research readily accept that we can improve and modify a number of agricultural practices in terms of fertilizers and pesticides. There is no doubt that that should be done, must be done, and will be done."

However, he points out that a whole range of people, from members of Congress to environmental organizations to the media, are misinterpreting the NRC report. They are looking at it as a set of prescriptions for all farms, when, in fact, much more research needs to be done before all farmers can adopt alternative methods.

He also says that some people look at the report and say, " 'What we really need is a lot more cultivation and a lot less use of herbicides.' But there is virtual agreement that cultivation [for weed control] has probably been the single biggest cause of soil erosion in North America."

Carpenter believes that the movement toward alternative agriculture will enhance Monsanto's sales. Monsanto is using biotechnology to develop pest- and virus-resistant crops, he says. These will eliminate the need for pesticides on some crops.

Monsanto is also using biotechnology to develop a soybean plant that is resistant to its Roundup herbicide (glyphosate), allowing farmers to use "one of the most environmentally friendly pesticides on corn and soybeans."

However, emphasizing protection of the environment in developing new pesticides has a downside, Carpenter says. "The pesticides that get on the market are going to be a lot better than the ones that are on the market now. But because of the high cost of development, you are not going to see pesticides developed for the small-acreage crops, and virtually all of our food crops fit into that category. So the very place where you would like to have new [safe] products will be the places that will be the last to get them."

John F. McCarthy, vice president for science and regulatory affairs at the National Agricultural Chemicals Association, expects that the movement toward alternative agriculture will cause "some reduced use of agricultural chemicals in some areas." But he doesn't think

Richard Thompson photo

Young pigs on this Iowa farm are raised in small units so the animals can get sunlight and exercise.

there will be major cutbacks. "We think there will still be a need to manage weeds, disease, and insects by the judicious use of chemicals," he says.

He believes industry will respond by developing materials that are active against weeds, diseases, and insects in very small amounts and so are less likely to get into groundwater or leave residues.

However, Frost & Sullivan Inc., a market research firm in New York City, predicts that growth in pesticide sales will level off after 1990, partly because more pesticide products will be restricted or banned.

Spokesmen for the fertilizer industry are taking a more negative approach. Harold F. Reetz Jr., director for the west central states of the Potash & Phosphate Institute, calls the NRC report "unscientific."

He doubts that alternative systems could work very well on a wide scale: "We have 100 years of research that has studied various systems, studied the low-input alternative systems along the way, and they've always fallen out as not being efficient and economically viable, and that's the reason we're not using them."

Basically, he believes that conventional agriculture itself is sustainable. "Some people seem to be on a witch-hunt to disprove what we have been doing—to say that the results of long-term research and extension programs and farmer practice are suddenly not good anymore. I've not seen any solid evidence that would tell me that reducing fertilizers and pesticides would solve either our economic or environmental problems."

In general, he doesn't believe farmers could significantly reduce the use of synthetic fertilizers by rotating crops or using other alternative methods and still produce good yields. "Whenever you remove crops from the farms, you're removing nutrients that have to be replaced," he says. He regards legumes and manure as unrealiable sources of nitrogen. Nitrogen from manure and legumes "is most likely released when the crop can't use it and thus it would be wasted and become a potential environmental hazard," he says. Therefore, fertilizer sales will not be affected by a move toward alternative methods, he says, unless farmers temporarily start depleting the soils. "Well-fertilized crops produce deeper roots and leave more crop residue to help soil erosion and better utilize nutrients deeper in the root zone," he adds.

Spokesmen for crop growers' associations fear that the NRC report on alternative agriculture will lead to a public push for stronger regulation of pesticides and fertilizers, so that farmers will lose some important weapons against pests. Already, they point out, many older useful pesticides for minor crops have not been available simply because of the high cost of reregistration, especially for products with expired patents and small sales volume.

"There will be a number of pesticides banned," says Dan W. Ragsdale, director of research for the National Corn Growers Association. "I am not totally convinced that it's necessary to do it. A lot of the good compounds are old ones, and no company is willing to invest money to defend some of these."

Most farmers also oppose extreme regulation against pesticides, such as total bans on many of them. Even farmers who currently use no pesticides want to have some available in case of an emergency. But the fear of immediate large-scale bans is probably unrealistic because such drastic measures have not even been proposed by environmental groups.

In the long run, the success or failure of alternative agriculture will probably depend on what farmers themselves decide to do. It will not depend on the fears of the public, or perhaps even very much on regulation. Alternative farming methods originated with farmers and the main force promoting these methods will probably remain with farmers as long as they continue to experiment and find methods that work.

But no matter how enthusiastic farmers are about alternative methods, broad change is not likely to come quickly without changes in federal farm policies and R&D priorities. The enthusiasm of farmers already using such methods is always tempered by admonitions to other farmers like: "Don't jump in too fast. Try it gradually, experiment on a small part of your acreage at first to see if you can manage it. Yields are often lower for the first few years when you try these new methods. Every farm is different and you must know how to manage yours very carefully, or you will fail." ☐

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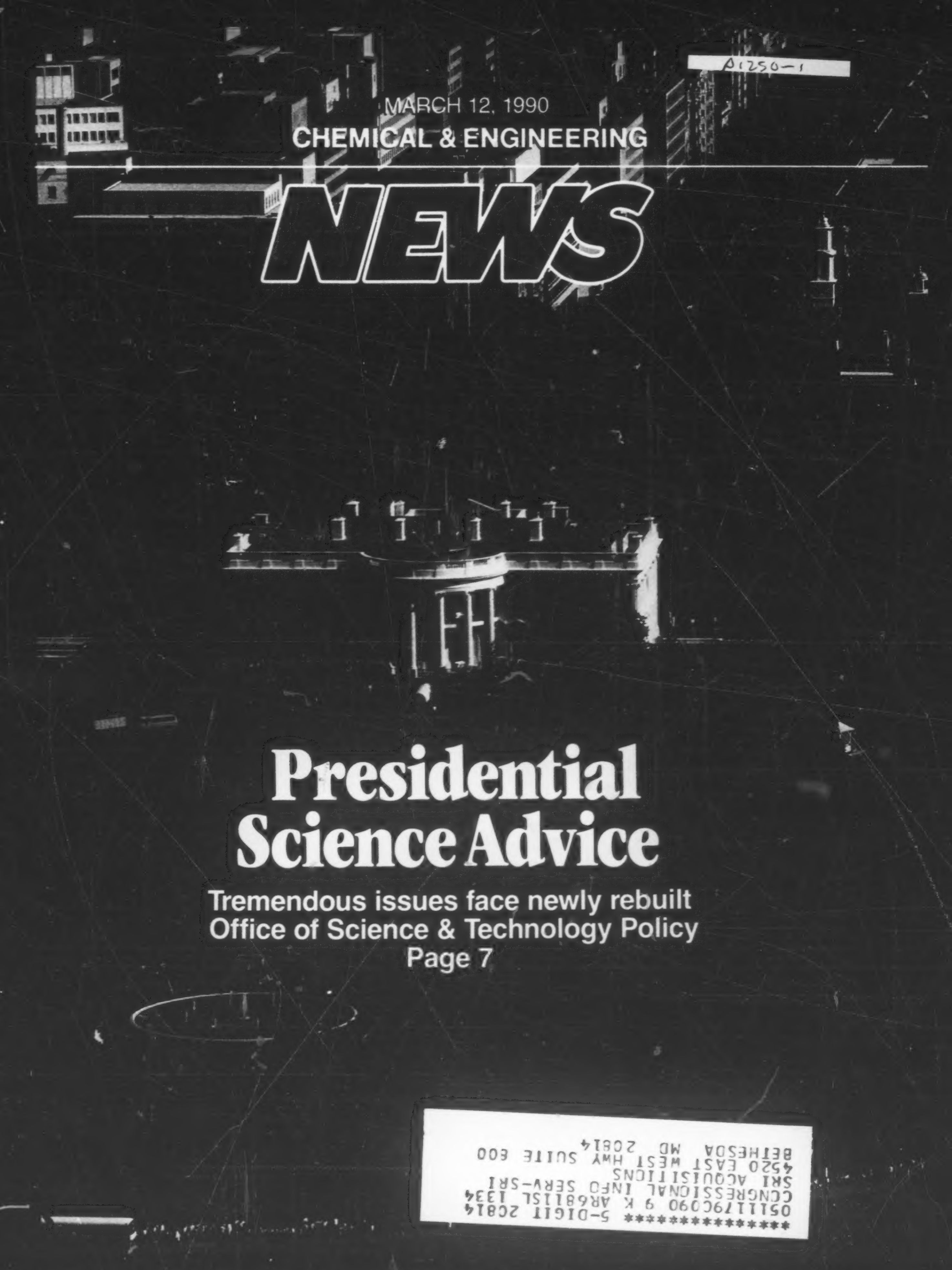

Presidential Science Advice

Tremendous issues face newly rebuilt Office of Science & Technology Policy
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CHEMICAL & ENGINEERING
NEWS
MARCH 12, 1990

News of the Week

- **EPA has added 25 organic chemicals to its list of compounds regulated as toxic in wastes, bringing the total list to 39.** **Page 4**
- **Major shakeup of Italy's troubled Enimont has been proposed by Raul Gardini, head of Ferruzzi Group, which holds majority control of Enimont.** **Page 5**
- **The Energy Department's plan to close down its research nuclear reactor, the Fast Flux Test Facility, at its Hanford, Wash., site, is running into heavy opposition.** **Page 5**
- **India's Supreme Court will meet this week to decide whether to dump last year's $470 million Bhopal settlement and resume civil and criminal trials.** **Page 6**
- **Ribozymes have been designed to cleave the RNA of HIV, and eventually may find use as therapeutic agents against the AIDS-causing virus.** **Page 6**

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Chemical productivity was up 2.3% in 1989, smallest rise in seven years, and chemical unit labor costs increased nearly 1%; increasing demand for soda ash is pinching capacity, triggering first major addition to U.S. capacity in a decade; asbestos removal firm, Advatex Associates, sees its business continuing to grow despite a recent report that asbestos risk to health has been overstated. **Page 16**

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Progress being made in AIDS research is emphasized in symposium at AAAS annual meeting; oxidative coupling technology may provide new route to olefins. **Page 24**

Perkin Medal

John E. Franz, discoverer of glyphosate, the active ingredient in Monsanto's Roundup herbicide, wins 1990 Perkin Medal. **Page 29**

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"Living with Radiation" takes a positive, nontechnical look at radiation's historical pros and cons, politics, and major issues of today. **Page 31**

News Focus

Science adviser D. Allan Bromley faces a number of challenges, both political and technological, as he constructs new policies for White House science advice. **Page 7**

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LETTERS

Chemical sensitivity

SIR: We appreciate C&EN's interest in the complex topic of chemical sensitivity. However, your recent article (C&EN, Feb. 26, page 4) requires some additional clarification.

Chemical sensitivity is by no means the property of clinical ecology. Occupational and environmental physicians, as well as allergists and other physicians, have begun to recognize this problem in their patients. It is important to separate the recognition of the problem of chemical sensitivity from the therapies that are being attempted to address the problem.

Unfortunately, efforts to clarify the nature of chemical sensitivity have been diverted by political attacks on the practices of clinical ecology, disputes over workers' compensation, and suits for damages in the courts. We are not arguing support for clinical ecology; we are arguing federal support for research into chemical sensitivity. Further, although an environmental unit is essential as a research tool in this endeavor, it is not the only way to find out if a person is chemically sensitive. Careful history taking, industrial hygiene workups of the workplace and home, and repeated observations of the patient are important practical tools. In this very controversial area it is essential to keep our focus on the central issue, and that is to understand the causes and consequences of chemical sensitivity.

Nicholas A. Ashford
Massachusetts Institute of Technology
Claudia S. Miller
University of Texas Health Sciences Center, San Antonio

Good scientists, good teachers?

SIR: I would like to respond to Duane Wolcott's letter (C&EN, Jan. 8, page 3) regarding enticements for industrial chemistry retirees to enter into careers as secondary school educators. I'm sure Wolcott's slur is unintentional, but his basic message is "teaching is easy, science is hard." I'm not a teacher and don't have intimate knowledge of the educational preparation a person requires for certification. However, I'm sure all those education courses aren't mere fluff.

If you have people teaching science who are highly skilled in a specialty discipline, but completely unprepared as teachers, you have university professors. In the three universities I attended during my undergraduate and graduate training, I encountered some really bad teachers. They were probably bad teachers because they never learned how to be good teachers. Luckily I encountered some really good teachers, also.

I don't believe high school students have the discipline, maturity, or resourcefulness to adapt to and persevere against a bad teacher the way one does in college. In addition, high schools aren't crammed with graduate teaching assistants to help you through the ordeal of a poor teacher.

As a final point, I'd like to say that I don't want my children taught by someone who is in the profession for the tax advantages. I want my kids taught by someone who loves teaching kids.

Tom Castle
Richland, Mich.

Environmental concerns

SIR: This past summer, we had the opportunity to participate in the *Exxon Valdez* oil spill cleanup in Alaska as a principal cleaner supplier. This allowed an early appreciation of the issues involved.

The regulatory people in Alaska imposed an initial goal of returning the environment to zero contamination and continue to require such an ideal objective. As laudable as this goal may be, it remains in an absolute sense as an impossible dream for several reasons.

First of all, Prince William Sound was not in a zero-contaminated condition before the spill. Human presence had long before altered this place, just as with any other human habitat. The processes of heating homes and buildings and of using cars, ships, and other vehicles, all contribute heat and carbon dioxide—not to mention prior, regular, and smaller spillages of fuels and other materials of modern civilization. And most certainly, these matters are receiving and will receive more rigorous attention from the regulators in Alaska now and in the future.

Now, we talk of "thermal pollution" as though this were immediately harmful to the environment, and the uncritical mind will accept such a thought. However, it does not take much thought to realize that the tropics contain the most biomass anywhere on the planet and that a modest increase almost anywhere on the globe—and particularly in colder climates—serves to favor life. Such warming should be looked upon as favorable to those—both human and animal—living in Alaska. Currently, the increase of animal life in the "thermally polluted" water about various nuclear reactors is seemingly incongruous, but nonetheless beneficial, environmental development.

Certainly, those in Alaska today

HAZARDOUS WASTES: EPA adds 25 organics to RCRA list

The Environmental Protection Agency has added 25 organic chemicals to the list of compounds regulated as toxic in wastes under the Resource Conservation & Recovery Act. The presence of any of these chemicals in solid waste or wastewater means the wastes will have to be treated under any applicable RCRA regulation. EPA says the regulations, four years in the making and which will cost industry up to $400 million annually for compliance, will save $3.8 billion in damage to groundwater resources.

Sylvia K. Lowrance, director of EPA's office of solid waste, says, "This rule will have a major impact on a number of people. It is going to lead to increased pressure on companies to change their processes to reduce the levels of these chemicals. We think more waste minimization will result." She also speculates that getting the contaminated wastes out of wastewater impoundments will result in fewer Superfund sites in the future.

The rule was issued on March 6 to comply with a court order from the U.S. District Court in the District of Columbia. The Environmental Defense Fund, a national legal and citizen's action group, had sued to get this and several other rules promulgated by the agency.

EPA says it expects 17,000 additional sources of waste to be affected by the new rule, including about 200 surface impoundments currently used to dispose of waste that will now be regulated under RCRA for the first time. Organizations operating these impoundments will have to close down or get permits to operate a treatment facility. Hardest hit by the rule will be petroleum refining, pulp and paper manufacturing, synthetic fibers, petroleum marketing, and organic chemicals industries.

The rule expands the so-called toxicity characteristics of hazardous waste. Under the 1984 amendments to RCRA, EPA is required to regulate a long list of specific wastes, but also any wastes that exhibit one of four characteristics. These are ignitability, corrosivity, reactivity, and toxicity. EPA had previously listed 14 chemicals as toxic—eight metals and six pesticides. The additions bring the toxic component list to 39. Thirteen other chemicals had been proposed for the expanded list, but seven of them break down in water and six others (considered the least toxic) have not been found in landfills in significant quantities.

Industry reaction to the new regulations has been light. "It is not much different from the proposed rule we last saw in 1987," comments Joe Mayhew, director of environmental programs at the Chemical Manufacturers Association. "We disagree with EPA on how many wastewater impoundments will be affected," Mayhew says. "We think it's going to be a much higher number." CMA believes EPA is using the wrong mathematical model for figuring leaching from these impoundments. "A lot of the surface impoundments were built in the 1970s and early 1980s to comply with the Clean Water Act. It's sort of ironic that this new law is cancelling the older one," Mayhew says.

Individually the impact will be greatest on smaller companies. A spokesman for the Synthetic Organic Chemical Manufacturers Association says hundreds of companies will fall under RCRA regulation for the first time, and many do not have the staff needed for compliance with such a complicated law. If processing changes are the only way to reduce the contaminant level in wastes, SOCMA is concerned some companies will just be forced out of business.

The full text of the regulations will be published in the *Federal Register* sometime in the next week. Most generators of hazardous wastes will have six months to comply with the regulations. Small-quantity generators must comply within one year.

David Hanson

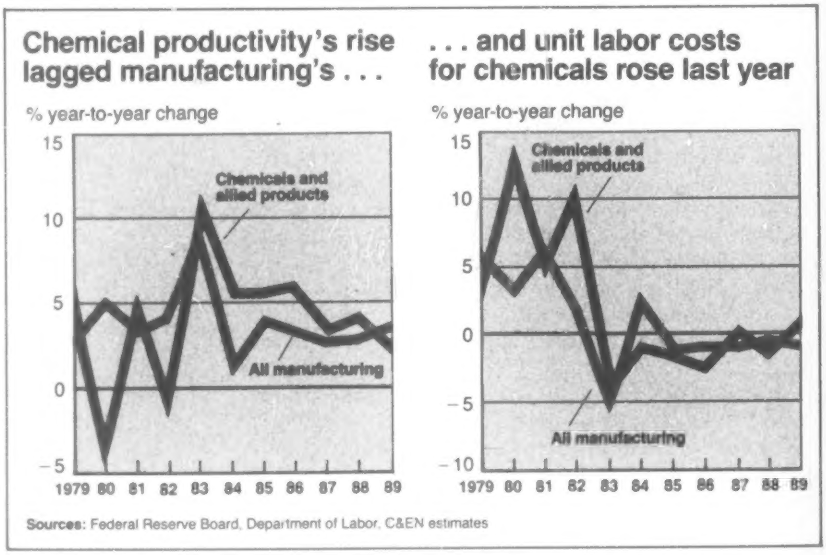
These organics in wastes will be regulated as hazardous

	Regulatory level (mg per L)
Benzene	0.5
Carbon tetrachloride	0.5
Chlordane	0.03
Chlorobenzene	100.0
Chloroform	6.0
***o*-Cresol**	200.0
***m*-Cresol**	200.0
***p*-Cresol**	200.0
1,4-Dichlorobenzene	7.5
1,2-Dichloroethane	0.5
1,1-Dichloroethylene	0.7
2,4-Dinitrotoluene	0.13
Heptachlor	0.008
Hexachlorobenzene	0.13
Hexachloro-1,3-butadiene	0.5
Hexachloroethane	3.0
Methyl ethyl ketone	200.0
Nitrobenzene	2.0
Pentachlorophenol	100.0
Pyridine	5.0
Tetrachloroethylene	0.7
Trichloroethylene	0.5
2,4,5-Trichlorophenol	400.0
2,4,6-Trichlorophenol	2.0
Vinyl chloride	0.2

Source: Environmental Protection Agency

Chemical Productivity Increased Modestly in 1989

Rise of 2.3% was smallest in seven years and trailed that for all manufacturing, possibly signaling slowdown; unit labor costs also up



Chemical productivity's rise lagged manufacturing's . . .

. . . and unit labor costs for chemicals rose last year

Sources: Federal Reserve Board, Department of Labor, C&EN estimates

Chemical industry productivity increased in 1989 from the previous year, but the increase was not so large as it has been for the six previous years. And unit labor costs also rose during the year. Thus, while companies produced chemicals more efficiently, it cost them more in wages to do it.

Using data published by the government, C&EN calculates that chemical productivity in 1989 increased 2.3% over the previous year to an index of 158.1 (1977 = 100). Productivity is defined as output per workhour, calculated by dividing production indexes by indexes for hours worked by production employees.

The 2.3% increase for 1989 compares with a 4.4% rise in 1988 over the previous year. Although productivity has been rising since 1983 for the chemicals and allied products industrial sector, the 2.3% increase is the lowest in that period. In 1982, productivity fell 1.5% from the previous year.

The smaller increase resulted from longer workhours for chemical industry employees. Chemical production itself increased 5.5% to an index of 160.2. Although the rise in workhours was not the highest in the postrecession era, it was relatively high at 3.1%, to an index of 101.3, and the differential between the increase in production and the

Despite chemical productivity improvement, wage increase causes rise in unit labor costs

Indexes, 1977 = 100	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
CHEMICALS AND ALLIED PRODUCTS											
Production	160.2	151.9	140.2	133.0	127.1	121.6	113.9	103.8	112.6	106.4	113.3
Workhours	101.3	98.3	94.7	92.6	94.1	95.0	93.9	95.2	101.7	101.0	103.1
Productivity[a]	158.1	154.5	148.0	143.6	135.1	128.0	121.3	109.0	110.7	105.3	109.9
Hourly production wages	203.1	197.0	192.4	186.1	180.1	172.7	164.8	155.0	141.8	129.2	118.2
Unit labor costs[b]	128.5	127.5	130.0	129.6	133.3	134.9	135.9	142.2	128.1	122.6	107.6
ALL MANUFACTURING											
Production	148.2	142.7	134.7	129.2	126.4	123.4	113.9	102.2	110.5	108.2	110.7
Workhours	96.1	96.1	93.4	92.0	93.1	94.8	88.2	87.0	97.9	98.9	106.4
Productivity[a]	154.2	148.5	144.2	140.4	135.8	130.2	129.1	117.5	112.9	109.4	104.0
Hourly production wages	184.3	179.1	174.0	171.1	166.9	161.5	155.4	149.6	140.7	128.1	118.0
Unit labor costs[b]	119.5	120.6	120.7	121.8	122.9	124.1	120.3	127.4	124.7	117.1	113.4

a Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. b Unit Labor costs are labor costs per unit of output, calculated by dividing index for wages by indexes for output per workhour. **Sources:** Federal Reserve Board, Department of Labor, C&EN estimates increase in workhours was the smallest it has been in that time.

The increase in productivity for chemicals lagged that for all manufacturing last year. This is bad news for chemicals and has been used in the past by some to signal a coming slowdown in the chemical economy as in 1980 and 1982. For all manufacturing industries in 1989, productivity rose 3.8% to an index of 154.2. This is one of the healthier rises for the measure in the past five years and is higher than the 3.0% increase in 1988.

Production for all manufacturing in 1989 rose 3.9% to an index of 148.2. But workhours were flat at 96.1. Thus the production rise almost directly translated to a productivity increase.

The inflationary news for chemicals and allied products in 1989 is that unit labor costs, which ideally decline as productivity increases, actually rose during the year. Unit labor costs, calculated by dividing the index for hourly wages by that for output per workhour, rose almost 1% in 1989 from the previous year to 128.5. In 1988, this index had fallen 1.9% from 1987.

The reason for the rise is that, while productivity was increasing 2.3%, hourly production wages were rising at a faster 3.1% rate.

Although the rise in unit labor costs is seemingly slight, it is the highest increase since the recession year of 1982, when unit labor costs increased a whopping 11%. The reason then was a drop in productivity combined with a huge 9% rise in production wages. This time, the rise is due entirely to the wage increase. Thus it has been moderated somewhat by the productivity increase.

In contrast, unit labor costs for all manufacturing declined almost 1% to an index of 119.5 in 1989, after being essentially flat the year before. For this broad category, hourly production wages rose 2.9% in 1989 to an index of 184.3, slower than the 3.8% productivity rise. In 1988, wages were up the same 2.9%, compared with a 3.0% rise in productivity. This is the seventh straight year that all manufacturing labor costs have fallen.

William Storck

Squeeze on soda ash capacity pushes expansion

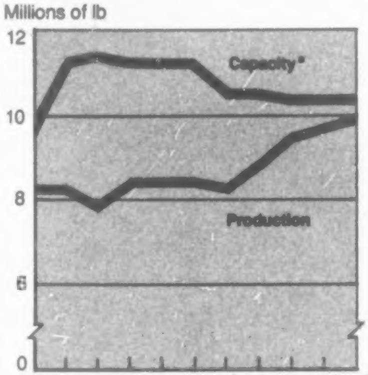
Demand for soda ash (sodium carbonate) is rising, ushering in the first major addition to U.S. capacity in 10 years. Plant expansion at Green River, Wyo., in a joint venture of Tenneco Minerals (a unit of Tenneco Inc.) and Asahi Glass that was disclosed late last month (C&EN, March 5, page 7), will add 600,000 tons per year of natural soda ash capacity by late 1992.

The most recent U.S. soda ash plant expansion was also at Green River in 1982, when Tenneco Minerals completed a plant now being incrementally expanded to a capacity of 1.25 million tons per year by the end of 1990.

Tenneco Minerals and Asahi Glass formed Tenneco Soda Ash Joint Venture to acquire Tenneco's existing soda ash facilities at Green River and to build the added capacity. Asahi will put $100 million into the project, will have a 20% share of the venture, and will obtain 370,000 tons per year of soda ash from the expanded plant output of 1.85 million tons per year. Asahi currently makes about 500,000 metric tons per year of soda ash synthetically in Japan and consumes large quantities in making glass and other products, says Kazuo Kamiya, executive vice president of Asahi Glass.

Total U.S. soda ash capacity will rise to more than 11.2 million tons when the addition is completed. Capacity was higher during the early 1980s when Allied Chemical produced soda ash synthetically in Syracuse, N.Y. The high cost of environmental control and low demand growth spurred shutdowns of synthetic soda ash capacity in the mid-1980s.

Capacity limits output of soda ash



a At beginning of year. b Shutdown of capacity for synthetic soda ash under way. c Estimated. d Forecast.
Sources: Bureau of Mines, C&EN estimates

During the past three years, U.S. production of soda ash has returned to the growth path, increasing about 6% annually. Because of current limited capacity, production in 1990 likely will expand only marginally over that in 1989, estimated at more than 9.8 million tons, says David R. Delling, president of Tenneco Minerals. Exports in 1989 are estimated to have totaled 2.8 million tons, or 29% of production. Imports were small, at about 150,000 tons last year.

World consumption of soda ash will grow more than 600,000 tons this year, Delling forecasts. He attributes the growth to increased use of glass, soaps and detergents, and other products using soda ash. In the U.S., however, consumption is forecast to hold at about the 7 million ton level of 1989 or to decline slightly because of the growing amount of recycled glass (cullet) used in making new glass.

Even considering a decline in soda ash use for glassmaking because of recycling, glass will continue to account for more than 50% of U.S. soda ash consumption. Bottles take most of the recycled glass and will continue to hold almost 40% of U.S. soda ash consumption. Flat glass takes about 10% of soda ash consumption, and glass fiber takes another 3%.

Some of the smaller uses of soda ash are growing in the U.S., points out Roger E. Shamel, president of Consulting Resources, a firm that includes soda ash in its continuous studies. Most of the growth is in applications where it can be substituted for caustic soda, the prices of which have increased rapidly. These uses include chemical manufacture and textile processing. Flue gas treatment has become a growing use of soda ash, although it receives strong competition from lime.

Bruce Greek

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■ **Rhône-Poulenc, Rorer Group sign an agreement to merge their pharmaceutical interests to form new health care company.** Page 7

■ **Polish environmental minister, Bronislaw Kaminski, succeeds in his efforts to garner funds from U.S., World Bank, among others for cleanup plan.** Page 8

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Pittsburgh Conference provides a showcase for more than 850 exhibitors of new analytical hardware and software. Page 26

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LETTERS

Graduate studies

SIR: I would like to respond to Elliot Scherr's letter concerning the relative ease of obtaining degrees in law, medicine, dentistry, and management compared to chemistry (C&EN, Jan. 15, page 2). As a law student with a Ph.D. (albeit in physics, not chemistry), I feel qualified to comment on his assertions, at least as far as law school is concerned.

My Ph.D. required 90 semester hours, 60 of which were course hours, over a five-year period. My J.D. degree will require 90 semester hours of courses over a three-year period, with a writing requirement that will take as much time and effort as a thesis. My law courses are not easier and do not require less work than my physics courses. The material is challenging and fully as intellectually rigorous as any class in physics. I spent one to two hours preparing for each classroom hour in graduate school; the rule of thumb in law school is three or more hours for each classroom hour. I worked hard in graduate school; I am working harder in law school.

Furthermore, there are no fellowships or assistantships for students in law, medicine, dentistry, or management. Unlike most graduate students in the sciences, students in these fields pay tuition and provide for their own living expenses. Many of my classmates work up to 20 hours per week in addition to attending school full time. I doubt they have many free weekends! I know I don't.

Mr. Scherr, please don't denigrate fields other than your own simply because you believe the work is easier or the starting salaries higher. A lawyer works just as hard as a physicist—or a chemist—does. Neither determines her own worth in the job market. Her employer does that.

Maria Reichmanis
Aiken, S.C.

SIR: I find myself in complete agreement with the opinion expressed in the letter by Elliot Scherr—namely, that poor financial incentive at the graduate student and postdoctoral levels is a major reason why fewer people are choosing careers in basic research. It is also a major cause of attrition among those who initially do opt for scientific careers.

As a married fourth-year chemistry graduate student who enjoys science greatly but who would also like to start a family sometime soon, I feel that I can speak with some authority on this issue. Quite frankly, financial concerns occupy my mind much more often than they should. These days, whenever someone asks me for advice regarding a career in science, I suggest that if they are not independently wealthy they should obtain a B.S. in engineering and then find a job.

There are ways to remedy this situation; for example, money. More specifically, the current stipend level for graduate students should be considered adequate for perhaps the first two years of graduate study. After completion of the usual requirements—comprehensive exams, course work, and research proposal defense—the stipend level should be increased substantially, say 30%. In a related matter, graduate students and their advisers should be required to submit a tentative timetable for completion of the student's Ph.D. by the beginning of the fourth year of graduate study. This would help reduce the incidence of long, financially uncertain stays in graduate school.

The postdoctoral pay scale is also poor, particularly in academia. Many of these positions offer salaries in the $18,000 to $20,000 range, which is, in my opinion, an outrageous sum to offer someone who has already completed between eight and 10 years of posthigh school education. I will almost certainly not pursue an academic career. University officials must redouble their efforts to secure adequate funding for research and reasonable pay scales for scientists. Industry must be persuaded to assume a share of this cost through governmental incentives (tax breaks) and university/industry partnerships. We must make it easier, in the financial sense, for gifted people to choose scientific careers.

Keith L. Constantine
Carnegie Mellon University

Percy Julian's achievements

SIR: The book review, "Blacks, Science, and American Education" (C&EN, Feb. 12, page 28), contains some statements about one black chemist, Percy L. Julian, that require correction, and some generalizations that need more careful consideration.

It is stated that Julian discovered cortisone, that he synthesized physostigmine, and that he was the first to synthesize the sex hormones. The facts are that Julian did prepare intermediates for the industrial production of steroid hormones, but he performed only one of

Raman spectrophotometer with CCD detector is used in pilot plants

Photo by Dow Chemical's Anne Leugers

damentals. The resulting quantitative analysis is linear up to 100% concentrations of analytes, she says, and turbid or opaque samples present no problems.

Leugers demonstrated analysis of a benzene-toluene stream in one second, as well as of a complex mixture of carbon tetrachloride, toluene, dioxane, and cyclohexane. In a real-world problem, the Dow team followed a polymerization reaction, sampling the spectrum every five seconds. They were able to study the mechanism of the addition of repeating units to the polymer chain. Leugers says it might be possible to feed optical cables from five different reactors to the same spectrophotometer.

The commercially available FT-Raman/IR spectrophotometer with CCD detector of Spex Industries uses the 752-nm output of a krypton ion laser for excitator, according to product manager Purcell. This excitation wavelength avoids not only fluorescence but also black-body radiation from darkly colored samples.

CCD is mounted in Spex Industries' FT-Raman/IR spectrophotometer

The system with spectrophotometer, CCD detector attachment, and data-collection software is priced at $60,000 (Circle 220).

Working with Job Bello, Purcell analyzed dry rice flour. He points out that after wetting with water and baking dry, even pure starch develops fluorescence, which interferes with Raman spectrometry. The Edison, N.J., workers also showed the recording of clear Raman spectra with such classic bad actors as rhodamine 6G and fluorescein isothiocyanate, which fluoresce strongly. They presented the Raman spectrum of a solid phthalocyanine that was opaque green-to-black in color.

Chemistry professor Alexander Scheeline of the University of Illinois, Urbana, has applied the combination of an échelle spectrograph with a CCD detector to investigations of species in plasma-enhanced chemical vapor deposition, a process used in semiconductor device fabrication. The spreading out of a wide spectral range allowed simultaneous measurements at multiple wavelengths with 0.03-nm resolution to minimize effects of what is called flicker noise.

Working with graduate students Cheryl A. Bye, Steven Rynders, and Duane L. Miller and supported by the National Science Foundation and Department of Energy, Scheeline observed Si-H in a plasma of silane and argon. Their computer program "pasted" the whole spectrum in strips on the CCD.

First they recorded the spectra in false colors, in which each color represented spectral intensity. Then they converted these to more conventional line spectra.

Staff scientist Michael J. Pelletier of Procter & Gamble's Miami Valley Laboratories, Cincinnati, Ohio, used the same approach to acquire Raman spectra of cyclohexane with 1-cm^{-1} resolution in one second. His band spectra were shown superimposed on the original false-color format.

A 5-nanosecond pulse from a 514.5-nm Nd:YAG (neodymium/yttrium-aluminum-garnet) laser was used by Pelletier to deliver a single 200-millijoule pulse to the sample. He suggests that the fast response of CCD detectors might make it possible to study irreversible processes with single, high-energy blasts of laser energy while avoiding interference from sample destruction.

Pelletier uses each adjacent cell of the CCD to represent 1 cm^{-1}. He described a computer-guided experiment in which two bands were 2 cm^{-1} apart. In this case, the bands would be resolved, because the data in each cell would be separated by one blank cell. But such bands could not be resolved if they were only 1 cm^{-1} apart. This is because data would show up in two adjacent cells, and the computer program would record them as part of one peak. ☐

Chiral drug analysis

Easily the most emotional issue in the Pittsburgh Conference technical sessions was that of chiral drugs. Of 1327 totally synthetic drugs marketed worldwide today, 528 are chiral, capable of existing as two or more optical isomers depending on the number of dissymmetric centers.

Often among enantiomers, only one is pharmacologically active, and the other or others are without effect, of different effect, toxic, or of unknown effect. Yet only 61 of the 528 chiral synthetic drugs are marketed as single enantiomers, while the other 467 are sold as racemates.

The Food & Drug Administration is expected within a couple of months to begin regulating the marketing of single enantiomers versus racemates in new drug submissions. A number of speakers explored the pharmacological implications of chiral drugs and presented recent progress in developing analytical methods that will be needed to generate data for new drug approvals.

The regulation of chiral drugs as it is evolving in the U.S. and elsewhere will produce a boomlet among products sold to meet them. Market researcher Philip Rotheim of Business Communications Co., Norwalk, Conn., predicts in the U.S. alone that sales of what he calls stereoselective chiral technology products will grow at 17.5% annually to $2.8 billion in 2000 from $465 million in 1989. Included among these are analytical instruments and reagents, resolving agents, and chiral intermediates and catalysts.

Pharmacology professor John Caldwell of St. Mary's Medical School (Imperial College), London, outlined the pharmacological situation. Chirality plays no role in such processes as absorption, distribution, and secretion of drugs and metabolites, he says. These processes depend on passive transport across lipid membranes. But active transport, protein binding, and metabolism depend on highly chiral receptors, channels, transport molecules, and enzymes. In these latter processes, fates and reaction rates of enantiomers can be very different.

And analytical chemist Irving W. Wainer of St. Jude Children's Research Hospital, Memphis, Tenn., expressed a note of caution when he told the audience that chiral excipients may affect bioavailability of chiral drugs.

Excipients are seemingly inactive fillers used to formulate dosage forms like pills, tablets, and capsules. The ones most commonly used are lactose and microcrystalline cellulose, and there is great current interest in cyclodextrins. Also, sucrose is often used to make syrups palatable. These may interact differently with different enantiomers in racemates to produce different rates of dissolution and absorption.

The chiral excipient issue will affect generic as well as pioneering drug companies, Wainer says. This is because generic drug makers must formulate for bioequivalence when submitting abbreviated new drug applications (NDAs) to FDA.

As new FDA regulations on chiral drugs approach, analytical chemists at drug firms will have to gauge the impact on their work load. Analytical chemist Ronald J. Bopp of Eli Lilly & Co., Indianapolis, assesses the forms the impact might take.

One question is the strategy the company takes in developing compounds from research. In one approach, the company might do exploratory studies on racemates before deciding whether to study enantiomers. The second approach might be to study enantiomers from the start. The second route would be expected to have greater impact on the analytical laboratory, because chemists would have to devise a chiral assay for every promising compound.

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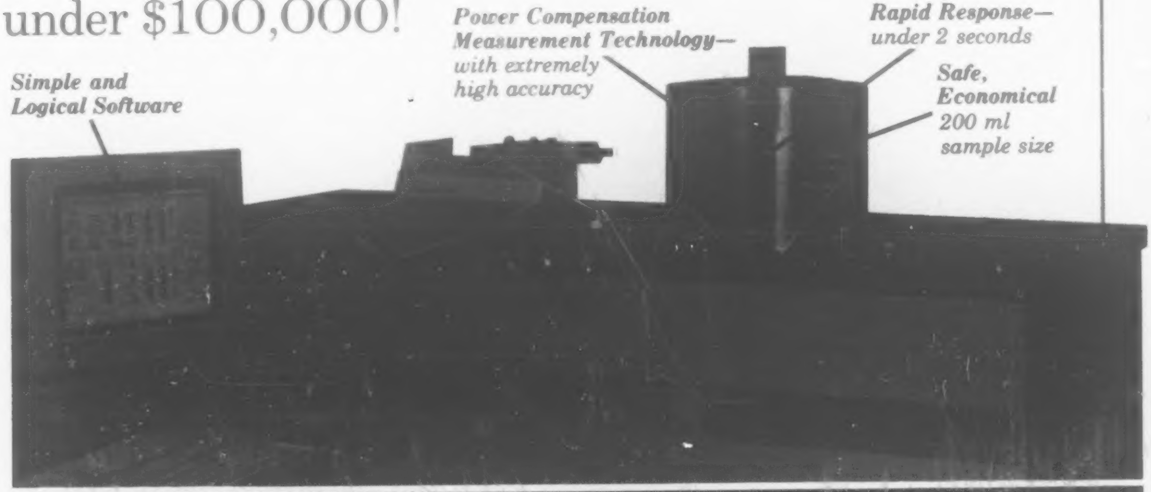
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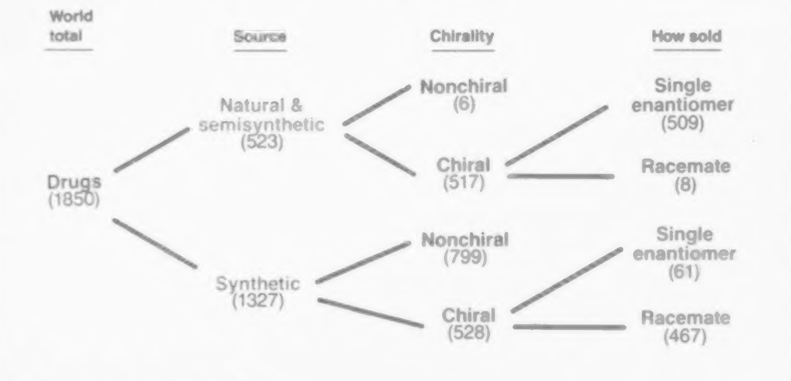
By thinking ahead, chemists could save labor by recognizing the information content of every assay. In chiral high-performance liquid chromatography (HPLC), for example, the chiral stationary phase slowly racemizes with use. But Bopp demonstrated to the audience that what is important is relative peak heights, so column racemization need not cause trouble.

There is also the optical purity of derivatizing reagents. Chemists might be distracted by considering whether an analyte is 100% optically pure but the reagent slightly impure, or whether the reagent is pure but the compound is a mixture of enantiomers. Again, proper interpretation of chromatograms and attention to relative peak heights solves the problem.

Chiral assays need not be devised for every determination. Achiral assays are sufficient to determine purities of starting materials and intermediates. Also, for studies of compounds with two dissymmetric centers, metabolic inversion at one carbon produces a diastereoisomer, not the opposite enantiomer, and an achiral assay again suffices.

At any rate, chemists should use separate achiral assays for material purity and chiral ones to determine proportions of enantiomers. This is because one chiral assay might not solve both problems. And assays should be devised so that the enantiomer present in lesser amount elutes first so that it not be swamped in the tailing of the greater.

Most synthetic chiral drugs sold as racemates



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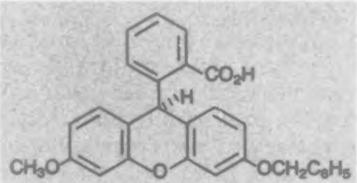
Instrumentation '90

Chiral dye measures optical purity of chiral compounds



O-Benzyl-O-methoxydihydrofluorescein

Principal methods of chiral assays are HPLC, gas chromatography (GC), and thin-layer chromatography (TLC). Interest is also growing in supercritical fluid (SCF) chromatography and capillary electrophoresis. Pharmacology professor Anthony F. Fell of the University of Bradford, England, has surveyed 800 literature references to chiral assays over the past two to three years. Of these, more than 70% are to HPLC, 15% to GC, and 5% to TLC.

The three basic chiral HPLC techniques are derivatization of analyte enantiomers with optically active reagents, use of a chiral column packing, and use of a chiral eluting solvent. Derivatizing any two analyte enantiomers with optically active reagents produces a mixture of two diastereoisomers, which can be separated on conventional, achiral columns.

The derivatization reaction is often laborious, but analytical chemistry professor Ira S. Krull of Northeastern University, Boston, describes a simple method based on chiral reagents immobilized on resins. Working with graduate students Chun-Xin Gao and Asa Trogen and supported by the National Science Foundation, Pfizer, and Supelco, he attaches chiral chains to crosslinked polystyrene consisting of a pyridinium, L-proline, and 9-hydroxymethylfluorene.

Passage of solutions of racemic alcohols, amines, or mercaptans through the resin resulted in transfer of a chiral proline-fluorene group to the hydroxyl, amino, or sulfhydryl groups. Krull says this method avoids separation steps and that he can regenerate the derivatizing resin.

As the University of Bradford's Fell points out, about 50 chiral column packings are commercially available for HPLC. Most of these are of the Pirkle type, named for analytical chemistry professor William H. Pirkle of the University of Illinois, Urbana-Champaign, who made many of them and put forth the theory of their efficacy.

Pirkle column packings bear chiral units consisting of acidic, basic, or π-acceptor groups or acidic, π-acceptor, and steric interaction (bulky) groups. Such arrangements provide the three-point-landing array that gives the best recognition of opposite enantiomers.

However, interest is growing in proteins as sources of chiral column packings. Of these, Fell says that α_1-acid glycoprotein (AGP) has the greatest range of temperatures, solvents, and compound types. The Bradford pharmacologist ascribes the success of AGP columns to invention of a new generation of them by ChromTech of Norsborg, Sweden, and tradenamed Chiral-AGP. Jörgen Hermansson of ChromTech separately surveyed the utility of the company's columns.

Despite the apparent abundance

Instrumentation '90

of useful materials, devising chiral HPLC assays that meet the needs of the drug industry can be long and arduous. Fell suggests that one shortcut might be use of computer-guided factorial experiments in which two variables are changed in each experiment and the response measured.

For example, he cites finding the best combination of pH and percent of acetonitrile added as a modifier. He plots a three-dimensional graph he calls a response surface with pH along one horizontal axis, percent of modifier along the other, and response—degree of separation—along the vertical axis.

Visual inspection of the graph shows a peak response, but the exact location of the maximum is uncertain. Fell uses a simplex analysis of the response surface to find the maximum. In this technique, he uses a series of triangulations beginning at the edge of the surface to ascend, crablike as he puts it, to the maximum. Each triangulation leads to a point representing the experimental conditions to be tried next.

The method has the advantage that the chemist need not know anything in advance about the response surface to explore it. But Fell admits the technique requires a lot of experiments, and the simplex analysis might get stuck at the top of a local maximum without finding the global maximum.

In such work, Fell advocates use of second-derivative functions of chromatogram peaks. These functions show with great sensitivity whether peaks are single or overlapped, and they indicate incipient separations.

One difficulty in devising chiral HPLC methods is that the samples are often blood serum or urine, and these contain other substances that must be separated to make the determination of enantiomer contents clearer. Wainer of St. Jude says the solution is often a coupled column approach, in which the sample passes first through an achiral compound to separate the chiral analyte of interest from others and then through a chiral column to assay the enantiomers. A switching valve diverts samples alternately to one detector to measure total concentration of racemic compound and a second detector to measure amounts of enantiomers.

But such methods can take hours. Faced with an emergency situation in which he had to monitor serum concentrations of (6*S*)-leucovorin in one patient, Wainer, measuring frequently, devised a method in which the sample passes first through a bovine serum albumin chiral com-

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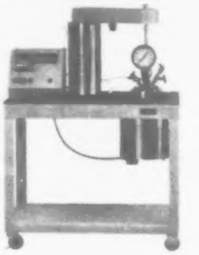

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pound and next through an achiral octadecyl column. The achiral column serves to compress the peaks. The resulting assay took only 70 minutes to do.

In addition to chiral HPLC, chiral gas chromatography (GC) has taken on new importance, thanks to analytical chemistry professor Daniel W. Armstrong of the University of Missouri, Rolla. His breakthrough was preparation of cyclodextrin derivatives that are both viscous liquids at room temperature and polar (they dissolve in water). Their liquid state eases the task of coating columns and gives a more dynamic interaction with chiral analytes.

The three cyclodextrins are cyclic oligomers of α-1,4 glucose units. α-Cyclodextrin is a hexamer, the β is a heptamer, and the γ is an octamer. The three hydroxyl groups of each glucose unit that are free for derivatization are called 2-OH, 3-OH, and 6-OH. Armstrong's group first reacts cyclodextrins with propylene oxide in aqueous sodium hydroxide, which may have attached 2-hydroxypropyl groups at 2-OHs. Subsequent reaction with methyl iodide produces permethyl-*O*-hydroxypropylcyclodextrins.

Columns coated with these derivatized cyclodextrins separated a wide variety of alcohols, amines, aminoalcohols, aminoethers, epoxides, larger cyclic ethers, lactones, and terpenes from one another and also separated enantiomers of each. The Missouri chemists convert amines and alcohols to trifluoroacetyl derivatives before injection onto columns. Armstrong notes that most of these compounds lack aromatic groups that seem necessary for chiral separations with HPLC.

Armstrong's coworkers in this project were polymer chemist research fellows Weiyong Li, Jo Dee Duncan, San-Chun Chang, and Randy A. Menges, along with research professor Apryll M. Stalcup at Rolla and polymer chemist Joseph Pitha at the National Institutes of Health. The Department of Energy supported their research.

Besides chiral HPLC and chiral GC, chiral supercritical fluid chromatography (SFC) has received attention from several research groups. Supercritical fluids are very dense gases maintained at high pressures above their critical temperatures. The critical temperature is the temperature above which a gas can no longer be liquefied by compression at any pressure. Typical supercritical fluids used in SFC are carbon dioxide, nitrous oxide, and sulfur hexafluoride.

Densities of supercritical fluids are 0.5 to 0.9 g per mL. These densities approach those of liquids commonly used as HPLC solvents. Thus solvent powers of supercritical fluids also approach those of polar liquid solvents. Such high solvent powers eliminate the need to vaporize analytes as is necessary in GC. Yet because they are gases, their flow rates are as high as that of helium in GC, leading to faster analyses than with HPLC. Indeed, chromatographers using SFC can program pressure rises into analyses, which means programing density profiles.

Chirality issues spark a growth industry

	U.S. sales ($ million)			Average annual growth rate	
Product category & application	1989	1995	2000	1989–95	1989–2000
Analytical instruments & reagents	$11.2	$14.4	$14.8	4.3%	2.6%
Drugs	9.0	10.0	9.0	1.8	0
Nondrug applications	2.2	4.4	5.8	12.1	9.2
Separation products	15.1	25.2	30.5	9.0	12.5
Drugs	12.1	17.7	18.3	6.5	3.8
Nondrug applications	3.0	7.5	12.2	16.5	13.5
Reaction materials & catalysts	438.5	1,280.7	2,749.1	19.5	18.2
Drugs	350.8	902.1	1,649.5	17.0	15.0
Nondrug applications	87.7	378.6	1,099.6	27.5	26.0
TOTAL	$464.8	$1,320.3	$2,794.4	19.0%	17.6%

Source: Business Communications Co.

Research professor Karin E. Markides of Brigham Young University, Provo, Utah, described separation of enantiomers of *trans*-stilbene oxide using an open tubular column coated with a chiral compound and employing flame-ionization detection. Analyses were 10 times as fast as with HPLC. And flame-ionization detection was sensitive to minute amounts of sample. Markides points out that the trend in the drug industry is toward ever more potent compounds, which means that analytical chemists will be called on to detect ever smaller amounts.

In his contribution to chiral thin-layer chromatography, Arnold Brossi turned to classical dye chemistry. Brossi, who heads the natural products section in the National Institute of Diabetes, Digestive & Kidney Diseases, Bethesda, Md., uses chiral derivatives of fluorescein.

Postdoctoral fellow Dragana Tadic synthesizes these by reduction of fluorescein to dihydrofluorescein with sodium borohydride and making a mixed benzyl methyl ether of the resulting dihydroxy compound. The different substituents render the methine carbon asymmetric, and Tadic resolves the enantiomeric dyes. These can be used to make ester and amide derivatives of racemic alcohols and amines.

The NIH workers developed chromatograms of separated esters and amides by treating first with ammonium hydroxide and then with iodine. Ammonia cleaves the ether groups, rendering the resulting phenolic compound susceptible to iodination to spots of deep red erythrosine. Brossi's future work includes making fluorescein derivatives that are more easily cleaved during development of chromatograms.

Brossi predicts that these chiral dyes will find use in characterization of chiral natural products as well as assays of synthetic drugs because of the fact that several alkaloids occur as mixtures of enantiomers. ◻

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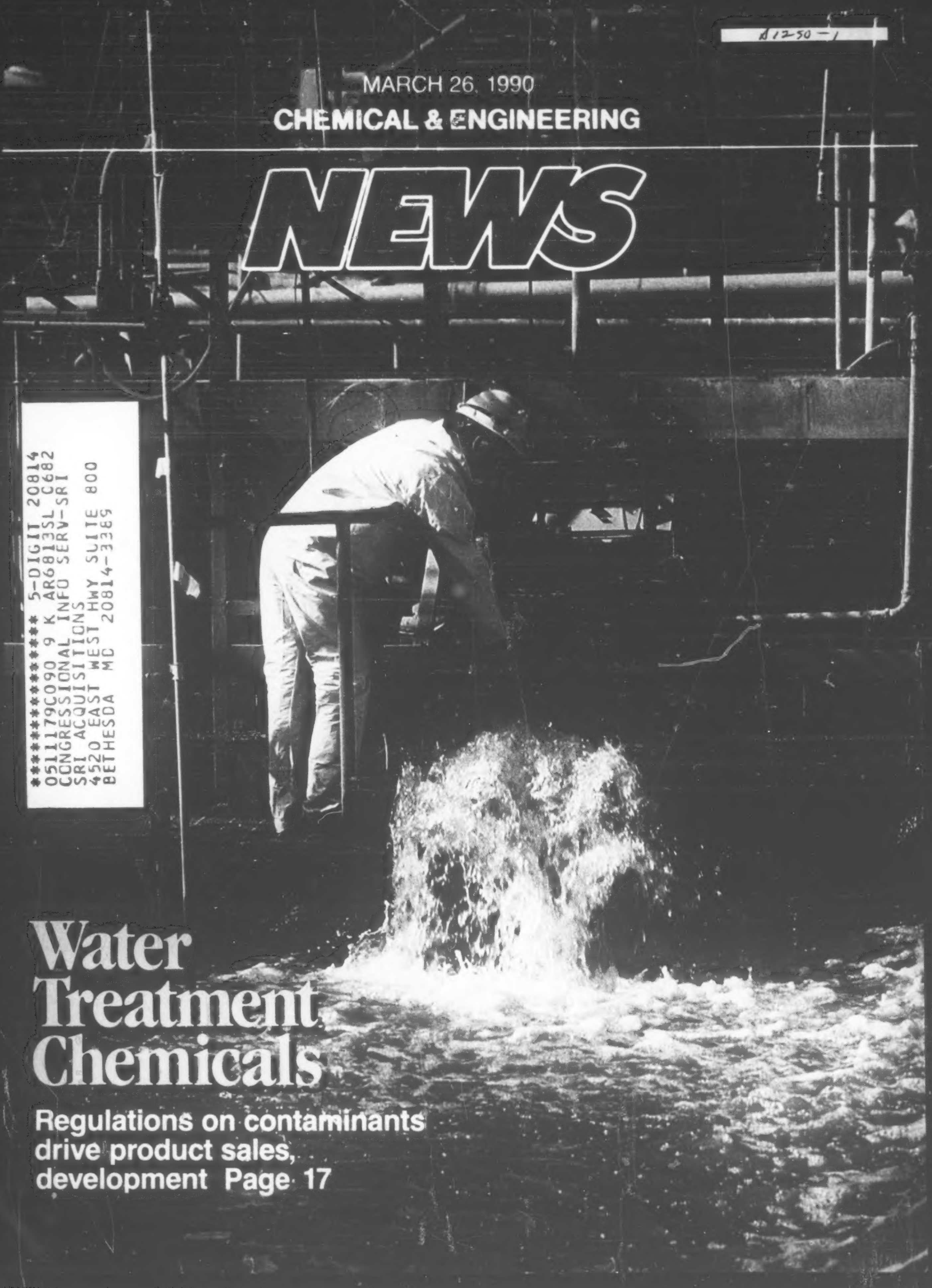
CHEMICAL & ENGINEERING
NEWS



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Water Treatment Chemicals

Regulations on contaminants drive product sales, development Page 17

CHEMICAL & ENGINEERING
NEWS
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News of the Week

- **Biomass burning is more widespread and dangerous to the environment than was previously thought, according to scientists attending first international conference dealing with this issue.** **Page 4**
- **Report released last week by the Defense Department describes plans for developing 20 technologies critical to national defense.** **Page 5**
- **New series of ruthenium-based catalysts provide very high activity and selectivity in converting methane to synthesis gas.** **Page 5**
- **Perking-Elmer has sold its electron-beam semiconductor fabrication business to Etec Corp. (a new firm formed from P-E employees), with five other firms participating in purchase.** **Page 6**
- **Report by coalition of farm and environmental groups criticizes efforts to produce herbicide-tolerant crops through biotechnology.** **Page 6**

Business

Canada may soon have three methyl *tert*-butyl plants, one each in the Alberta, Quebec, and Ontario provinces. **Page 9**

Government

New proposals to levy taxes on pollutants are being studied by House committee. **Page 11**

Factors affecting the completion of a global chemical arms ban are considered during recent AAAS symposium. **Page 12**

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New software product, NMRgraf, combines molecular modeling techniques with nuclear magnetic resonance spectroscopy data to create 3-D structural models of large molecules. **Page 16**

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Cover: Technician samples industrial effluent stream. Photo courtesy of Interox

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LETTERS

CHEMICAL SAFETY

Silane distillation explosion

SIR: We have, on two separate occasions, recently experienced explosions during the distillation of 1,2-dichlorotetramethyldisilane, a procedure that we have previously carried out numerous times without incident. In the first case, a distillation was inadvertently carried out in air atmosphere rather than under the usual conditions of a nitrogen purge. In the second example, a detonation occurred in a system that was supposedly under N_2 purge. Both explosions occurred at the liquid-gas interface in the glass distillation head and were accompanied by a fire that self-extinguished before proceeding down the column. The impact of the detonation was sufficient to shatter the apparatus, fortunately without injury.

Compounds containing strained Si-Si bonds are known to undergo spontaneous air oxidation to the siloxane but in general chloro/methyl di- and polysilanes are reported to be "stable to air oxidation" [*J. Organomet. Chem.*, **94,** 367 (1975)]. We cannot be sure that the explosion was the result of oxidation as opposed to rapid hydrolysis of the silyl chloride (or some combination of both processes) but it has been our experience that hydrolysis of hot chlorosilanes, while extremely exothermic, does not result in explosion.

We recommend that anyone using this class of chloromethyldisilanes use adequate precaution when handling these compounds at elevated temperatures under atmospheric conditions.

Jonathan D. Rich
Manager, Silicone Materials Program
GE Corporate Research & Development

Flammable ammonia

SIR: Regarding Ernest J. Tews' letter (C&EN, Jan. 15, page 2), I too have been disturbed by the classification of ammonia as a nonflammable gas. Of course it is flammable.

One of the experiments I performed for firemen during my many years of teaching about hazardous chemicals was to feed ammonia gas and oxygen into an ordinary lab Meeker burner, adjust the gas flows, and ignite the flame with a propane torch. The bright yellow flame was proof enough.

Fred C. Trager
Barberton, Ohio

Chem Matters for high schools

SIR: I'm pleased to inform J. J. Jacobson (C&EN, Dec. 11, 1989, page 3) and any other readers who recall the periodical *Chemistry*, that the ACS Education Division initiated a new and eminently successful high school chemistry publication, *Chem Matters,* more than six years ago. With a current circulation of approximately 60,000 copies, this award-winning periodical supports the popularization and enrichment of chemistry for students through a variety of appealing and motivational articles, features, and activities.

I urge Jacobson and others not yet familiar with this excellent ACS initiative to become acquainted with *Chem Matters* and promote its extended use among schools and teachers in their areas. Subscription information may be obtained from the Education Division, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036, phone (202) 872-4590.

Henry Heikkinen
Chairman, Chem Matters *Policy Board*
Professor of Chemistry
University of Northern Colorado

Cover credit

SIR: It may be of interest to your readers that the instrument shown on the cover of C&EN, Feb. 26, is the Perkin-Elmer Cetus DNA Thermal Cycler. The person using it is Elena D. Katz, a senior researcher in our Biotechnology Product Department engaged in methods development for PCR technology.

Edward Bloch
Director, Corporate Relations
Perkin-Elmer Corp.
Norwalk, Conn.

Corrections

- Feb. 26, page 37: The University of Illinois' Chicago campus was misidentified as UI's Chicago Circle campus.
- March 12, page 19: The correct phone number for information on ordering EPA's report, "Methods To Manage and Control Plastic Wastes," is (800) 424-9346.

BIOMASS BURNING: Environment hurt more than thought

Biomass burning—the burning of rain forests, savannah grasslands, agricultural wastes, and other biological materials—is far more widespread and dangerous to the environment than was previously thought, according to scientists attending the first international conference on biomass burning, held last week in Williamsburg, Va.

About 180 scientists and policymakers from more than 25 countries attended the conference, which was sponsored by seven organizations, led by the American Geophysical Union and the National Aeronautics & Space Administration.

Biomass burning creates several greenhouse gases, as well as chemically active gases that cause acid rain and tropospheric ozone pollution. Researchers estimate that, in total, about 5% of Earth's surface is burned each year.

Just five years ago, the scientific community gave little attention to biomass burning, says conference organizer Joel S. Levine, a senior research scientist at NASA's Langley Research Center. But recently, it has become the subject of intensive research.

Biomass burning large source of global emissions

Million metric tons per year as C, N, or O	All combustion sources[a]	% from biomass
Carbon dioxide (gross)	8700	40%
Carbon dioxide (net)[b]	7000	26
Carbon monoxide	1100	32
Methane	380	10
Nonmethane hydrocarbons	100	24
Ozone	1100	38
Ammonia	44	12
Nitrogen oxides (NO_x)	40	21
Nitrous oxide (N_2O)	13	6

a Including fossil fuel and burning and all biomass burning. b Carbon dioxide released by all combustion minus that taken up by replacement vegetation. Source: Meinrat O. Andreae, Max Planck Institute for Chemistry

Scientific estimates of the amount of biomass burned in the world each year are greater than they were a decade ago. Paul J. Crutzen, director of the atmospheric chemistry department at Max Planck Institute for Chemistry in Mainz, West Germany, says that some 3 billion to 5 billion metric tons of biomass carbon are burned annually, compared with 5 billion to 7 billion metric tons of fossil fuel carbon.

Meinrat O. Andreae, director of the biogeochemistry department at Max Planck Institute, calculates that the carbon dioxide from biomass burning is about 40% of that produced from all sources annually, and that the carbon dioxide from deforestation alone accounts for about 26%. Burning of the savannah in Africa is responsible for about one third of the global biomass burning.

Photographs taken by astronauts show that during the burning (dry) season, smoke areas in the Amazon have increased from scattered fires covering abut 300,000 sq km in 1973 to continental-scale palls over about 3 million sq km in 1985 and 1988, reports Charles A. Wood, space scientist at NASA's Johnson Space Center in Houston. "You had better look at Earth in the near future if you want to see it, because soon you won't be able to see it," he warns.

Biomass burning has a number of important impacts. The nitrogen oxides, hydrocarbons, and carbon monoxide released in the combustion process lead to the formation of tropospheric ozone. Also, the nitric oxides and formic and acetic acids created during combustion cause acid rain. In addition, biomass burning, by altering soil nutrients, increases the emission of methane and various oxides of nitrogen from the soil for many months after the burn.

Biomass burning affects global climate in several ways, especially by creating vast amounts of the greenhouse gases carbon dioxide and methane. The changes in land surface resulting from biomass burning also alter climate. Because deforested land is not nearly so efficient as a tropical rain forest at returning rainfall to the atmosphere, burning vast stretches of rain forest reduces precipitation in the tropics.

As a result of the enormous quantities of biomass burned each year in the Amazon and in Africa, ozone levels there in the burning season are close to those in the industrialized world. Ozone concentrations in Africa are almost high enough to be toxic to plants, Andreae reports.

During the burning season, rain over virgin rain forests in central Africa and South America is as acidic as that which falls in Europe and North America. Jane Dignon, a researcher at Lawrence Livermore National Laboratory, California, attributes the high acidity in the tropics to biomass burning.

Information about almost every aspect of biomass burning is quite uncertain. Though experts generally agree that the amount of burning has accelerated greatly in the past few decades, the current global extent, the percentages of various ecosystems being burned, and the frequency of burn are known only roughly.

"We believe that more than 95% of global burning is human initiated and can be stopped once the world's leaders are aware of its detrimental environmental consequences," Levine says. "This is one area of science where we can effect a reversal

NASA photo

Agricultural fires form white smoke plumes in infrared photo from space shuttle over East African coast

of a dangerous trend by raising awareness and public education."

Last Friday, conference scientists discussed global burning on a teleconference broadcast live on Public Broadcasting Service stations and by satellite around the world. Viewers questioned the panelists by using a toll-free phone number.

Bette Hileman

Plan for vital defense technologies issued

Efforts are moving on at least three fronts toward formulating a national technology policy. For example, a report released last week describes plans for developing 20 technologies rated by the Department of Defense as the "most critical to ensuring the long-term qualitative superiority of U.S. weapon systems."

Under a Congressional mandate, the White House Office of Science & Technology Policy is forming a National Critical Technologies Panel. This high-level panel will prepare by late fall the first of a series of biennial studies of up to 30 crucial defense and civilian technologies. Moreover, OSTP will soon issue a first, broad overview of technology policy.

Meanwhile, the Commerce Department is expected shortly to issue a report on critical technologies.

DOD's 272-page report is the second annual Critical Technologies Plan it has prepared (C&EN, April 3, 1989, page 24). Concerned that the U.S. is losing its technological edge, Congress has mandated in the past two defense authorization acts that DOD, in consultation with the Department of Energy, draw up such a plan and submit it by March 15 each year to the Senate and House armed services committees. The report will be the focus of a hearing this week before the Senate Armed Services Subcommittee on Defense Industry & Technology, chaired by Sen. Jeff Bingaman (D.-N.M.), initiator of this and the OSTP mandate.

The 20 technologies include all four chemically related ones from last year's list, plus an addition. Two technologies—composite materials, and semiconductor materials and microelectronic circuits—rank in the highest of three priority groups, Group A. Three others—biotechnology materials and processes, high energy density (energy dense) materials, and superconductivity—are in Group C, which contains mainly emerging technologies. High energy density materials, which include improved rocket propellants and explosives, are new to the list.

For each technology, the report describes the reasons for its selection, current and projected manufacturing capabilities, development plans, related R&D in the public and private sectors, potential benefits for weapon systems and the U.S. industrial base, and current funding. DOD and DOE are spending $3.1 billion on 19 of the technologies (funding of one is classified). Nuclear technologies are not included and will be addressed later separately.

The report also compares the U.S.'s competitive status versus other nations. As in 1989, Japan is "significantly ahead in some niches of technology" in five areas: semiconductor materials and microelectronic circuits, machine intelligence and robotics, photonics, superconductivity, and biotechnology materials and processes. The Soviet Union has a significant lead in some niches of just one technology, pulsed power. It is generally on a par with the U.S. in high energy density materials and two other areas.

The report is a "significant improvement over last year's," says Bingaman. It is the "most comprehensive effort thus far to sort out our defense technology priorities," and has substantial industry input. He hopes it will be "a building block" toward a national technology policy.

However, he adds, "it is still not a plan to get from here to where we want to be." Thus, DOD does not designate a lead agency for each technology, as Congress asked. "This is still more of a report on critical technologies than a plan for achieving specific goals by specific organizations in specific time frames with specific resources."

Richard Seltzer

New, powerful catalysts for methane conversion

Catalytic chemists at Oxford University in the U.K. have discovered a new series of ruthenium-based catalysts that provide very high activity and selectivity in converting methane to synthesis gas.

A research group, including Anthony K. Cheetham, of Oxford's chemical crystallography laboratory, has demonstrated that catalysts of the type $Ln_2Ru_2O_7$ (where Ln is a lanthanide) are extraordinarily active for the partial oxidation of methane to synthesis gas—for example, lowering the temperature required for the reaction from more than 1200 °C to only about 775 °C [*Nature*, **344,** 319 (1990)]. These catalysts are ruthenium analogs of a number of rare-earth/tin oxides that have been used for the oxidative coupling of methane to ethylene.

Unlike most synthesis gas generating reactions, the partial oxidation reaction ($CH_4 + \frac{1}{2}O_2 \rightarrow CO + 2H_2$) is mildly exothermic and produces a synthesis gas with an unusually low H/CO ratio. This may be advantageous in future commercial operations by eliminating the need for a second-stage reactor to adjust the H/CO ratio, as is done today.

Cheetham's work is supported by the Gas Research Institute, Chicago, which has just renewed his funding for an extended period. According

Canada Could Get Three MTBE Plants

Canadian chemical companies are jumping into the octane booster, methyl *tert*-butyl ether (MTBE), in a big way. Right now, there are no MTBE plants in Canada. Soon there could be three.

The first to come on stream likely will be a 500,000 metric-ton-per-year unit to be built near Edmonton, Alberta, by a joint venture of Finland's Neste Oy and Petro-Canada.

Two other Canadian MTBE ventures are on the drawing board. Soquip, the Quebec provincial government's oil and gas holding company, may build a 500,000 metric-ton-per-year plant near Montreal, along with Italy's Ente Nazionale Idrocarburi (ENI) and Noverco (Montreal). And Nova Petrochemical could become the third Canadian MTBE producer with a 400,000 to 500,000 metric-ton-per-year plant the company is considering—possibly at Sarnia, Ontario, but neither site nor capacity has been set yet.

If all three of these plants are actually built, Canada's MTBE capacity could zoom from zero to about 1.5 million metric tons in a few years. And the Canadian MTBE producers should have little trouble marketing their output.

Demand for MTBE in the U.S. as an oxygenated fuel additive is soaring. There's little doubt that these Canadian companies have their eyes on the U.S. market. And exporting MTBE from Canada to the U.S. will become much easier after April 30. That's when, under the accelerated tariff cuts negotiated as part of the Canada-U.S. Free Trade Agreement, duties on MTBE will be eliminated. MTBE coming into the U.S. from Canada now has a tariff of 5.6% ad valorem.

Meanwhile, Canadian demand for MTBE also is likely to increase dramatically. Canada plans to eliminate lead additives in gasoline and has advanced the effective date of this move by two years, from December 1992 to December 1990.

For several years, Canada has been reducing the level of lead allowed in gasoline. The present lead level allowable is 0.2 g per L. When lead is eliminated from use in all gasoline except that fuel used in critical farm, marine, and commercial vehicles, there will be a demand for octane in Canada that MTBE and other oxygenated fuels will likely be called upon to meet.

MTBE capacity would be 1.5 million metric tons

Thousands of metric tons per year		Capacity
Petro-Canada, Neste Oy	Edmonton, Alta.	500
Soquip, ENI, Noverco	Montreal, Que.	500
Nova Petrochemical	Sarnia, Ont.	500[a]
TOTAL		1500

[a] Possible capacity range is 400,000 to 500,000 metric tons.

And last month, the Canadian government proposed regulations to reduce automotive emissions, which, if adopted, would take effect with the 1995 model year. The goal is to cut nitrogen oxide emissions 60% and hydrocarbon emissions 29%. To meet these standards, refiners no doubt would have to add MTBE, ethanol, or methanol to their gasoline.

In addition to potentially attractive markets, Canadian MTBE producers can depend upon a ready supply of raw materials. There are several methanol producers in Canada. And the country has an abundant supply of natural gas and crude oil from which to get butylenes.

Construction should start on the Neste Oy/Petro-Canada plant in Alberta next month and the unit could be on stream by the end of next year. Nameplate capacity is 500,000 metric tons per year but design capacity is 530,000 metric tons.

Already, the partners are looking ahead to expanding their MTBE plant beyond its 500,000 metric ton capacity, if the MTBE market develops as expected. Methanol for the unit may come from Celanese Canada's nearby 900,000 metric-ton-per-year plant, but the company is still negotiating for methanol supplies, and other sources are available.

Nova Petrochemical has yet to make a go/no-go decision on its MTBE plant. "It's still under consideration and is of significant interest," says Keith McKee, who until recently was the company's general manager of business development.

In addition to the site and capacity, also still undecided is whether the company will build the MTBE plant alone or with another company. Nova had been considering a joint venture with Pequiven, the Venezuelan petrochemical company and Italy's ENI. "This is still an option," says McKee. No matter where the plant is built, the methanol feedstock would come from the company's own methanol plant at Medicine Hat, Alberta.

Most tenuous of the three Canadian MTBE projects right now is the one slated for Montreal. That's because the project depends upon whether a pipeline is built from Sarnia to Montreal to carry natural gas liquids to the Montreal area. The pipeline would be built by Interprovincial Pipe Line.

Spearheading the pipeline project is Soligaz, a consortium of companies that includes Quebec's Soquip, one of the companies involved in the proposed MTBE plant. The NGL pipeline already has been approved in principle by the federal government, but it must await final approval of the National Energy Board.

Interprovincial Pipe Line plans to seek final board approval this summer. If approved, construction could start early next year. Without the pipeline, the MTBE plant probably would not be built in Montreal because adequate feedstock would not be available.

Earl Anderson

Interox photo

Technicians sample and test for contaminants from aerated lagoon

Water Treatment Chemicals: Tighter Rules Drive Demand

Ann M. Thayer
C&EN Northeast News Bureau

In the U.S., about 325 billion gal of water are used every day. Almost all of this water, used primarily by industry, municipalities (excluding residential and commercial), and power-generating utilities, must be treated. Physical, chemical, and biological methods are used for treating water to remove pollutants or contaminants that can interfere with its use, or to allow for its discharge into surface waters.

The overall market for water treatment chemicals totaled $2.32 billion in 1988, according to a study by Freedonia Group, a Cleveland-based research group. Nearly 12.9 billion lb of water treatment chemicals were sold that year. Because water treatment chemicals include both commodity and specialty-grade chemicals, the sizes of the major markets can differ widely when considered by dollar value or volume.

The industrial market, which covers a broad range of manufacturing, processing, and refining industries, accounted for close to a third of the total volume of chemicals used, but nearly 47% of the dollar value. Major industries, such as paper manufacturing, chemical processing, and refining, rely more heavily on higher margin, lower volume specialty chemicals used as coagulants, dispersants, and corrosion inhibitors. In contrast, the municipal, utility, and institutional markets are dominated by the lower price, higher volume commodity chemicals such as chlorine, lime, caustic soda, and soda ash. These markets accounted for about 48%, or $1.1 billion, of the value and about 53%, or about 7 billion lb, of the volume of materials sold. Similarly, the residential and commercial market used slightly more than 12% in volume, but spent only 5.5% of the total in 1988.

The markets for specialty chemicals are growing faster than those for commodity chemicals, explains William Weizer, vice president of the chemical and plastics division of Freedonia Group. The overall water treatment chemicals market is projected to expand 6.7% annually for the next few years, reaching $3.2 billion by 1993. However, this represents only a 1.6% annual growth in volume. Industry use of specialty treatment chemicals will grow at a level 1.3% higher than that of the overall market. Chemical processing and refining industries will lead this growth at 9.5% per year through 1993. However, in the more mature municipal and institutional markets, growth will be nearly flat.

Chemical demand will be stimulated by increasingly stringent environmental regulations, says Weizer, and by tighter control over industrial wastewater.

The markets for water treatment chemicals can be broken down into five major applications—cooling, boiler, waste, supply, and process water. Cooling water, about 29% of the overall market, is the largest application for water treatment chemicals. The remaining four applications areas are nearly the same size.

In terms of real growth, the applications markets are growing slowly, says Peter Thomas, director

Federal laws limit chemicals in water

How water is regulated under federal law depends primarily on the its past and current usage. Under several laws relating to water, the Environmental Protection Agency oversees and directs state management of water quality standards. For example, pollutants entering surface waters are regulated under the Clean Water Act. The Safe Drinking Water Act protects drinking water sources and sets drinking water standards. Groundwater and hazardous wastewater are regulated under Superfund and the Resource Conservation and Recovery Act.

The Clean Water Act regulates contaminants discharged in municipal and industrial wastewaters. Under this act, which was amended and strengthened in 1987, EPA established technology-based limits on 66 pollutants from a list of 126 priority pollutants. These regulations were promulgated in response to a settlement in a 1976 suit brought by the Natural Resources Defense Council. Based on the best available technologies economically achievable and on the best practicable control technologies currently available, these limits are known as the organic chemicals, plastics, and synthetic fibers guidelines. They were challenged in court by members of affected industries, but were upheld in a March 1989 decision.

Effluent guidelines under the Clean Water Act are used by states to issue National Pollutant Discharge Elimination System permits. These permits specify the amounts of different pollutants that may be directly discharged, and they set up monitoring and reporting schedules. Pretreatment standards for industrial discharges into municipal treatment plants, as well as minimum treatment standards for municipalities, are also part of the Clean Water Act's guidelines.

The impact of the organic chemicals, plastics, and synthetic fibers guidelines and the 1987 Clean Water Act amendments have yet to be felt. Issues raised in the amendments are just now beginning to be addressed by EPA. These include regulations on nonpoint source pollution and a permitting program for storm water discharges by industry and municipalities, regulations on the management and disposal of residual sludges from water treatment processes, and further enforcement of compliance with effluent toxicity regulations.

On the water supply side, the Safe Drinking Water Act directs monitoring and treatment of drinking water and aims to minimize contamination of surface- and groundwaters. It focuses on the presence of lead, radionuclides, and microbiological contaminants, as well as on organic and inorganic chemicals. Monitoring for currently unregulated organics and inorganics is also directed.

Amendments to this act in 1986 directed EPA to establish maximum contaminant levels and best available technologies on 83 pollutants by June 1989. States are required to adopt regulations at least as strict as the standards outlined by EPA. To date, about 15 final maximum contaminant levels have been established, about another 40 have been proposed, and 25 more are expected this year. The regulations become effective 18 months after promulgation, and final limits for all 83 contaminants are not expected until 1992. In 1991, EPA is also expected to propose rules for disinfectants and their by-products, such as chlorinated organics.

of marketing at Drew Industrial, a division of Ashland Chemical. The market for boiler water treatments is estimated to grow at less than 2%, whereas cooling water uses will grow 2 to 4%. High capacity utilization helps to keep water treatment chemical markets stable, but decreases in manufacturing and production—which can occur in a slower economy or a recession—can hurt growth for the industry. The market for wastewater treatment will see the most real growth, at 5 to 7%, says Thomas, with activity attributed primarily to environmental concerns.

Treatments for most uses of water consist of proprietary specialty formulations supplied by water treatment companies. The industry is dominated by six firms—Betz Laboratories, Calgon, Dearborn, Dexter (Mogul), Drew Industrial, and Nalco Chemical. To varying extents and strengths, each firm services all the major markets. The smaller Olin Water Services and Hercules Water Management businesses have been acquired in the past few years by Drew and Calgon, respectively. Chemed's Dubois Chemicals business has about $25 million in sales in the water treatment area. The wide variety of commodity and specialty chemicals used in formulations are supplied by numerous chemical manufacturers serving other industries in addition to water treatment.

In addition to selling chemical formulations, water treatment companies charge for services associated with the application of their products and often for the lease of equipment. "The water treatment industry is an operating expense dominated market," explains Thomas M. Laronge, a technical consultant based in Vancouver, Wash. Customers tend to be interested only in how much it costs on a daily basis to have their water treatment needs for uninterrupted and efficient plant operations addressed. Thus, the services provided are often used as a means for differentiating what are otherwise similar chemicals, comments Laronge. "Water treatment is really a process, rather than a product, that occurs between the end user and the water treatment company."

This process includes analyzing a plant's water, developing a material balance for a desired application, and determining the appropriate treatment to minimize the effects of contaminants or naturally occurring impurities in water. It also can include implementing, monitoring, and upgrading the water treatment process, and providing analytical laboratory services for customers. When problems arise, explains Laronge, they're usually the result of a breakdown in the overall treatment process rather than in product quality.

To compete in what is a generally mature market for chemicals, the major companies stress the importance of their added services, technological advances in product design and application, and product quality. The "value-added services" have contributed to the profitability of specialty formulations that are sold as part of water treatment programs. They include the design of water treatments, computer-based process monitoring and maintenance, emergency response services, regulatory and environmental consulting, and even the disposal of shipping containers for the chemicals.

"As a result of trying to meet quality control demands, the trend in some industries is to enter sole-supplier relationships," says a spokesman for Betz Laboratories in Trevose, Pa. For the large companies, which may patent their products, providing services is another means to compete with "over-the-counter" competition from those who attempt to copy and supply formulations. Betz and Nalco Chemical, of Naperville, Ill., are the two largest water treatment companies. Betz had 1989 sales of $249 million for its heavy-industry water treatment divisions, and Nalco had 1989 sales over $270 million for its water and waste treatment division.

Calgon, based in Pittsburgh, ranks itself about third in the industry, but as a subsidiary of Merck & Co., it does not report separate sales figures for its business. Drew, based in Boonton, N.J., and Dearborn (a division of W. R. Grace & Co.), based in Lake Zurich, Ill., fall somewhere in the middle range of the six largest companies. Although Grace reported 1988 sales in water treatment of $183 million, its figure includes other water treatment operations. Dexter Water Management Systems, a division of Dexter Corp. located in Chagrin Falls, Ohio, had sales estimated well below $100 million in 1989.

"One of the aspects of our business that has really taken off in the past several years is the control aspect," says Bruce Grotefend, director of marketing for Calgon. Control systems are produced under various tradenames by all the major companies. The goal is to automate the water treatment process by computer monitoring, chemical feed control, and data management.

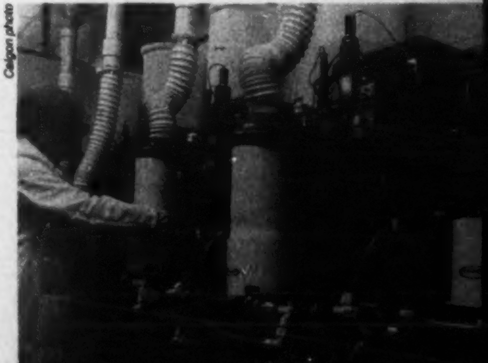
Adds Ed James, director of cooling product management at Betz Industrial: "It's an emphasis and a commitment to bring the control of water systems up to the level of the control that companies have on their processes." Such systems allow for steady-state operation of chemical or refining processes and include correcting for changes in pH brought about by accidental overfeeds of acids, treating for changes in contaminants from various processes, and adjusting loads when other processes or equipment are brought online. This can result in efficient use of equipment, decreased maintenance, energy savings, and limited production shutdowns. Monitoring systems also alert the water treatment company to emergencies.

Another service offered, in response to customer concerns about the handling and disposal of drums, is alternative delivery methods for chemicals. "Nalco is working to get out of the drum business," says Mary Kay Kaufmann, marketing manager of Nalco's basic industry group. Semibulk containers of about 300 gal are becoming widely used by the industry to deliver and store chemicals. The water treatment companies collect, clean, and refill these semibulk containers. Capital costs for the containers, as well as costs for the extra handling, disposal of any hazardous chemicals after cleaning, and refilling the containers, have become part of the water treatment chemical supplier's business and may be passed on to customers.

By far the most important service, according to the water treatment companies, is that of being consultants to customers who want assurance that the chemicals are applied properly. In this role, many companies may require that only their chemical treatments be used with equipment leased to customers. Still, underlying all the service aspects is the basic question of how well the water treatment process works.

Water treatment is chemically complex, containing many variables related to local water conditions and characteristics—namely, the amounts and types of impurities and contaminants present. Stable mixtures of a few to a dozen chemicals, in which each chemical performs properly under conditions of pH, temperature, and water composition and purity, must be developed. R&D plays a significant role in the water treatment industry's efforts to produce new products and optimize formulations. Nalco and Betz spend an estimated 4% of sales, or about $10 million, on R&D. Formulations are sometimes custom blended to take into account local conditions, water quality, how the water is used, and the design and construction of the plant equipment.

"In the specialty chemical market," says Kaufmann, "the challenge is to develop new innovations in [chemical treatment] technology." Yet, in any one of the larger applications for water, the types of problems to be addressed are fairly consistent. For example, in cooling and boiler water treatments, the concerns center on corrosion and scale inhibition. Corrosion, an oxidation-reduction reaction in which a metal surface is converted to its oxide, is caused by the presence of dissolved oxygen and is affected by the presence of suspended solids, temperature, pH, hardness, and ion concentration. Scaling is caused by the deposition of insoluble salts on heat transfer surfaces. A third concern, preventing biological growth, can be added to the list for cooling water treatment. Together, these


Calgon photo

Pilot plant cooling tower system is used as model in R&D

problems result in heat transfer losses and decreased efficiency, metal degradation and pipeline failure, and blockages and flow problems.

Concern is focusing on some of the water treatment chemicals used in industrial cooling and boiler water treatments because of the potential for being discharged in wastewater. "The environmental atmosphere, with stricter regulations, is changing the business for both producers and users of water treatment chemicals," says Thomas of Drew. "It's more costly to meet newer federal [Environmental Protection Agency] requirements." For the water treatment companies, this means more testing, more data collection, and supplying more information on the chemicals used in the products.

Meeting new regulations and stricter limitations on chemical contaminants in water can be achieved at a cost, explains Thomas, "but that cost is likely to be high." And, although tighter rules make doing business more expensive and complicated, they do signal growth for the industry, which is expected to expand—not only with more treatment required, but with new technologies and products developed to treat previously unregulated contaminants.

For users of water treatment chemicals, environmental concerns mean complying with federal guidelines on discharges of waste chemicals from industrial processes. To address concerns from both ends, water treatment firms are providing environmental counseling services. These services are aimed at keeping customers aware of regulations that pertain to their discharge permits, helping them come into compliance with new effluent guidelines, and addressing concerns about the treatment chemicals themselves.

"[Addressing concerns] can require us to change a program to one that is more environmentally acceptable," says Tom Schmucker, director of boiler product management at Betz Industrial. Biocides, used to prevent algal, fungal, and bacterial contamination in cooling water systems, are an example. Like pesticides, all biocides are registered under the Federal Insecticide, Fungicide & Rodenticide Act and come under

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pH adjusters/softeners are largest volume chemicals

Millions of lb	Paper industry	Chemical/ refining	Other industry[a]	Municipal/ utilities	Residential/ commercial	Total
Coagulants/flocculants	856	172	234	628	4	1,894
Filter media/adsorbents[b]	11	28	56	148	18	261
Oxidizers/disinfectants[c]	227	114	179	1444	222	2,186
pH adjusters/softeners	680	209	1008	4369	0	6,266
Corrosion inhibitors	81	129	184	9	0	403
Sodium chloride	0	67	82	0	1342	1,491
Other	20	21	35	286	0	362
TOTAL	1875	740	1778	6884	1586	12,863
TOTAL ($ millions)	$396	$267	$427	$1106	$128	

Note: 1988 U.S. markets. a Includes textile, food and beverages, paints and coatings, electronics, rubber and plastics, metals, mining, and oil and gas. b Physical filtering methods not included. c Synthetic organic biocides not included. **Source:** Freedonia Group

close environmental scrutiny when discharged as part of cooling water. If an effective replacement cannot be found, the goal is to then look for materials that can be neutralized or detoxified by a subsequent treatment.

Biocidal treatments can be oxidizing or nonoxidizing chemicals and include chlorine, chlorine dioxide, bromine and bromine compounds, sodium or calcium hypochlorite, isothiazoline, organochlorine or organobromine compounds, and quaternary ammonium salts. Their effectiveness depends upon the type of biological growth, pH sensitivity, and presence of other contaminants. Concentrations used range from less than 0.1 mg per L to as much as a few tens of milligrams per L of water treated.

Bromine hydantoins and quaternary ammonium compounds are receiving attention as replacements for chlorine, says Doug Murray, business manager for water treatment chemicals at Lonza. The problems in handling pressurized gas, as well as concerns about the formation of toxic chlorinated organics in waste streams, are contributing to the move away from chlorine. For disinfection, chlorine gas has long been one of the least expensive alternatives.

Hydrazine, a suspected carcinogen, used as an oxygen scavenger and metal passivator to prevent corrosion in boiler and steam systems, is another water treatment chemical about which there is concern. Dearborn has patented the use of diethylhydroylamine as a replacement for hydrazine. Cyclohexylamines and sulfites are also used as oxygen scavengers in corrosion control. Some of the neutralizing amines, notes Schmucker, are now generating concern.

Most attention in the industry has focused on chromates once used extensively for corrosion inhibition in cooling water equipment. Chromates protect metal alloys from corrosion by producing a protective metal oxide film on the metal surface. Concern about the presence of chromium is directed at airborne heavy metals from misting off open cooling towers and in wastewater discharges. Chromates were banned in January for use in comfort cooling (air-conditioning) uses, and limitations on other uses are generally expected.

"To some degree [the ban] has been anticipated," explains James of Betz, "and is not a problem because we already have nonchromate programs in place." Replacement products are based on inorganic phosphates and polyphosphates, or all-organic treatments, used in various mixtures with zinc, phosphonates, and dispersants. Economic considerations and the type of cooling system employed (recirculating or once through) will determine which treatment method is most cost-effective.

Only about 10% of all U.S. plant locations continue to use chromates. However, the refining industry still

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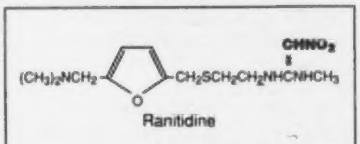

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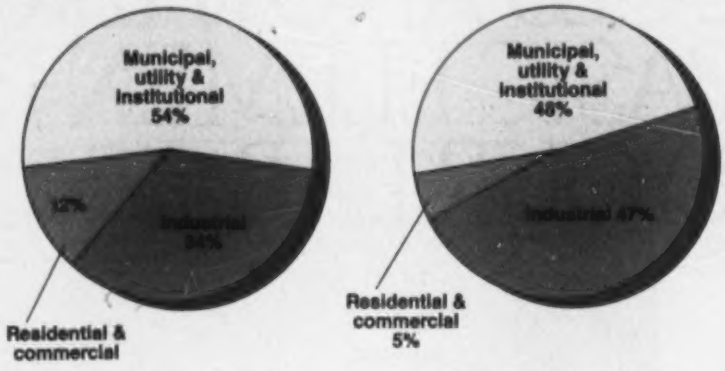
Municipal uses dominate chemicals consumption . . .

. . . but industry spending is nearly as much



1988 total = 12.9 billion lb

1988 total = $2.3 billion

Source: Freedonia Group

relies heavily on their use. "It's a common misconception that chromates are still desired and necessary," says James. "They are really a very low percentage of our sales." The overall market for corrosion inhibitors was 403 million lb in 1988, or $395 million, primarily for use in industrial, rather than municipal or residential, applications. Growth is expected to be 9% per year for corrosion inhibitors with the more expensive replacements and the eventual changeover of the refining industry to nonchromate programs contributing to this growth.

Chromate programs tend to be more forgiving than nonchromate programs when errors occur, explains Kaufmann of Nalco. Chromates operate best in a pH range of 6 to 7, which is a more corrosive environment, but one in which there is less likelihood of the formation of scale. However, nonchromate programs operate at higher pH and, if not properly controlled, scale can form rapidly and detrimentally affect heat transfer. Under the older chromate programs, the consequences were slower, longer term corrosion, rather than scale, and less immediate effects on heat transfer and operation. "As a result," she adds, "automated control and feed [of the treatment chemicals] is becoming much more emphasized."

Hand in hand with the change to nonchromate programs have been improvements in scale control agents. Common scales include magnesium hydroxide and calcium carbonate, calcium sulfate, and calcium phosphate, formed from the presence of magnesium and calcium "hardness" ions. Calcium carbonate scale formation can be inhibited by polymeric inorganic phosphates, generally the sodium and potassium salts. These include salts of pyrophosphate, tripolyphosphate, and hexametaphosphate, which can suppress crystal formation on the metal surface. Organic phosphates and phosphonates may also be used. Organic polymers including polyacrylate, polyacrylamides, polymethacrylate, polymaleates, and their copolymers are being introduced as effective scale control agents. At low molecular weights, 1000 to 10,000 atomic mass units, and in milligrams-per-liter quantities, the polymers inhibit crystal growth and act as dispersants that inhibit precipitation. Suspended solids or nonadherent scale sludges can be removed with the water.

The increased concentration of phosphates to prevent corrosion can result in the formation of greater amounts of calcium phosphate deposits. According to Calgon, new inhibitors such as acrylic acid-hydroxypropylacrylate copolymer, styrene sulfonic acid-maleic acid copolymer, acrylic acid-sulfonic acid copolymer, and phosphino/acrylic acid-organosulfonic acid copolymer have been developed. Other possible dispersants are lignin- or cellulose-based and are more easily degraded than synthetic polymers in wastewater, but must be used in higher concentrations and can contribute to foaming.

Defoamers account for 76 million lb, or about 4%, of the water treatment chemicals market. Dispersants, surfactants, and emulsifiers are also used to suspend solids, corrosion by-products, biological matter, and dirt. Deemulsifiers are used to break up oils and greases that would otherwise foul heat exchange systems. Market figures for dispersants are included in the overall category of coagulants and flocculants.

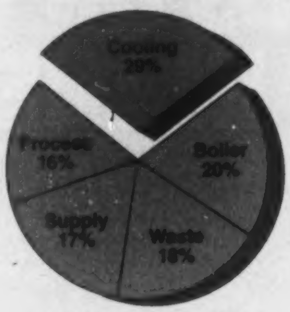
Depending on the characteristics of influent water for industrial uses, particularly in boiler water use where evaporation causes the concentration of impurities, the water may require pretreatment to remove solids, minerals, and impurities. A clarification step may involve pH adjustment and treatment with coagulants and flocculants to remove dissolved solids and some mineral salts. These treatments are closely related to those used in wastewater treatment. Other pretreatments may include demineralization by ion-exchange or ultrafiltration methods.

Ultrafiltration methods are generally based on membrane separation technologies about which few technical details are publicly available. In reverse osmosis, semipermeable membranes are used to separate pure water from water containing salts or other materials such as organics or solids. Purified water flows through the membrane, rejecting dissolved materials when an external pressure is applied to reverse the osmotic process.

Cellulose acetate and polyamide are some of the more common materials used in what are complicated, multilayer membrane systems. Dow, Du Pont, and Allied-Signal are major producers of membrane systems used largely in the desalination of brackish water as a source for drinking water. Advances in membrane technology, including more effective ones that are resistant to microbiological contamination, are expanding large-scale water treatment applications. But the cost of installation and operation can be prohibitive.

Ion-exchange resins, in columns

Cooling water uses lead treatment chemicals market



1987 total = $2 billion

Source: Kline & Co.

or beds, are used extensively to soften water by swapping ions bound to the resin with those present in the water. For example, in water softening with a cation-exchange resin, magnesium and calcium ions are replaced with sodium. Resins can be anionic or cationic. When used for complete demineralization of water, both positively and negatively charged ions are removed and exchanged with hydrogen and hydroxyl ions in a stepwise or mixed resin process. Since organics and solids will foul the resins, ion exchange generally follows other treatments.

Ion-exchange resins are predominantly styrene-based polymers and copolymers with divinylbenzene. Phenolic- and acrylic-based resins are also used. Acrylic resins are an important part of Rohm & Haas' ion-exchange resin business, adds Jack Gallagher, the company's North American regional director and worldwide codirector for ion-exchange resins. Rohm & Haas and Dow are two of the leading manufacturers of ion-exchange resins. The market for ion-exchange resins reached 126 million lb valued at $209 million in 1988. The resins are generally sold through water treatment companies or distributors for installation in new equipment or replacement in existing equipment. Water treatment companies often service ion-exchange systems, and treatment acids or bases will regenerate the resins for repeated use.

Although easy to control and resulting in high-purity water, particularly for chemical process or power-generating uses, ion exchange is a relatively expensive treatment method. Resin costs average more than $1.50 per lb, and, although they can be regenerated and reused, there are also capital costs for equipment. Operating costs, including replacing fouled or degraded resins, and downtime for regenerating or replacing resin beds are among the financial considerations.

Ion-exchange resins are used extensively in the municipal and institutional markets for water softening and other drinking water purification applications. The water treatment market is a very mature market, comments Gallagher. Specialty applications for removing heavy metals, producing ultrapure water for electronics applications, removing radionuclides in nuclear power plants, and for separation processes in chemical processing are the growing markets and will require resins with unique performance characteristics. Ion-exchange resins are also finding more use in treating water for nitrite, nitrate, and some organic contaminants.

Although regulatory pressures may cause a rise in the application of specialized treatment techniques to remove small amounts of specific contaminants, industrial and municipal wastewater treatment, historically, has focused on simple solids removal, pH adjustment, and disinfection.

Wastewater treatment consists of three major stages. Primary treatment is the removal of solids and biological oxygen-demanding substances by settling, filtering, or screening the water. Secondary treatment most often involves biological treatment. This includes activated sludge or attached growth treatments in which naturally occurring aerobic microbiological organisms digest contaminants in the water. Tertiary, or advanced, treatment may follow to remove low levels of organic or inorganic toxic contaminants.

Wastewater from industrial sources can contain more unusual chemicals, such as metals and organics, or more concentrated or toxic pollutants than municipal sources. Most industrial wastewater is treated on site in plant treatment facilities and directly discharged under National Pollutant Discharge Elimination System permits and must be treated to meet effluent standards. Wastewater that is discharged by a plant into a municipal treatment facility must be pretreated to meet certain standards set by the municipality based on its ability to handle certain contaminants. The permitted limits—based on EPA organic chemicals, plastics, and synthetic fibers effluent guidelines under the Clean Water Act—are set and enforced on the state and local levels. State water quality standards tend to be more stringent than EPA guidelines.

Along with industrial cooling and boiler water applications, polymers are finding extensive use in wastewater treatment to remove suspended materials. In primary or secondary clarification steps, and in later sludge-dewatering steps, polymers are replacing more traditional co-

Ultrox photo

In new water treatment process, UV light activates hydrogen peroxide

Demand for water treatment chemicals to grow

Millions of lb/$ millions	1988		1993		2000		% annual growth	
							Volume	Value
Coagulants/flocculants	1,894	$ 363	1,985	$ 500	2,085	$ 765	1.5%	6.4%
Filter media/adsorbents	261	320	315	470	400	770	0.8	7.6
Oxidizers/disinfectants	2,186	733	2,380	945	2,675	1280	3.6	4.8
pH adjusters/softeners	6,266	256	6,780	330	7,425	450	1.7	4.8
Corrosion inhibitors	403	395	515	645	715	1110	1.4	9.0
Defoamers	76	95	90	125	110	175	4.9	5.2
Fluorides	286	128	300	160	320	205	3.1	4.0
Sodium chloride	1,491	34	1,585	40	1,690	45	0.9	2.4
TOTAL	**12,863**	**$2324**	**13,950**	**$3215**	**15,420**	**$4800**	**2.7%**	**6.2%**

Source: Freedonia Group

Water treatment chemicals fall into several general classes based on their properties and function. Whether for industrial processes, municipal uses, or waste removal, water treatments are generally mixtures of different inorganic and organic chemicals, both commodity and specialty, designed to address specific needs.

Coagulants and flocculants: These materials neutralize charged colloidal and suspended materials, allowing them to agglomerate. They include inorganic chemicals such as aluminum sulfate (alum), ferric chloride, ferric sulfate, sodium aluminate, and lime (CaO). High molecular weight organic polyelectrolytes can be designed to function as coagulants, whereas lower molecular weight polymers function as dispersants to prevent scale formation or fouling. Such polymers are generally based on polyacrylamide, often copolymerized with monomers containing charged groups, polyamines, or polyacrylates.

Filter media and adsorbents: Activated carbon and ion-exchange resins account for the largest portion of adsorbent media in water treatment. Ion-exchange resins, used to demineralize water, often consist of cationic or anionic polystyrene-based copolymers. Granular activated carbon is used in columns or beds to remove water-soluble organics.

Oxidizers and disinfectants: Used to remove biological contamination, odors, and taste from water, these chemicals cover a wide range of organic and inorganic treatments. Chlorine gas and chlorine derivatives (chlorine dioxide, sodium and calcium hypochlorites) are commonly used. Bromine and bromine compounds are gaining in use as possible replacements to chlorine-donating inorganics and organics. Other oxidizing treatments include potassium permanganate, hydrogen peroxide, and ozone.

pH adjusters and softeners: Caustic soda, soda ash, lime, acids, and bases are used to change the acidity or alkalinity of water. Combined with coagulants and flocculants, they can be used to form insoluble salts, which can be removed by precipitation. Water softening involves the formation and precipitation of insoluble calcium and magnesium salts to remove the metal "hardness" ions that form scale on surfaces exposed to water.

Corrosion inhibitors: Corrosion, an oxidation-reduction reaction in the presence of dissolved oxygen, is a major cause of metal degradation in water systems. The process can be inhibited through the formation of protective layers on the metal. Chromate salts, inorganic and organic phosphates and polyphosphates, or all-organic treatments are common corrosion inhibitors.

Defoamers: Used primarily in industrial applications, such as pulp and paper manufacturing, defoamers include oil-based antifoam agents.

Fluorides and sodium chloride: These materials are used almost entirely in the municipal and residential markets for water fluoridation and water softening uses, respectively.

agulants and flocculants such as aluminum sulfate (alum), ferric chloride, ferric sulfate, sodium aluminate, and lime. Still, the inorganic commodity chemicals dominated the market for coagulants and flocculants in 1988. Alum accounted for 59%, or 1.1 billion lb, but only 31% of the market value. Alum is used to a very large extent in raw water treatment, municipal wastewater treatment, and water treatment in paper manufacturing. In contrast, at more than 13 times the price per pound, organic treatments accounted for only 8% by weight, but 55% in dollar sales. Iron salts and other inorganics make up the remaining market.

When used, alum forms a gelatinous floc of aluminum hydroxide that adsorbs and settles out suspended and collodial matter. Positively charged inorganic coagulants neutralize negatively charged colloidal species and cause them to agglomerate. Other inorganic chemical treatments, including lime and caustic soda, precipitate out metal hydroxides or form insoluble inorganic salts such as calcium carbonate or calcium sulfate. Added coagulants can help to increase the speed of settling of the precipitated material. Because of the quantity needed, the inorganic treatment chemicals themselves contribute greatly to the volume of sludge produced by flocculation. Polymers, although more sensitive to aqueous conditions, are used in much smaller quantities and produce sludges with a higher percentage of solids to trapped water.

The water-soluble polymers are all high molecular weight polyelectrolytes, on the order of 10^5 to 10^7 amu, such as polyacrylamides, polyamines, polyacrylates, and their copolymers. The polymer's behavior is determined by a combination of chemical structure and molecular weight. Through copolymerization with different functional monomers, the ionic character of the materials as anionic, cationic, or neutral species can be determined. For example, in polyacrylamide polymers, the amide groups are hydrolyzed to form carboxylate groups, the anionic nature determined by the degree of ionization. Copolymerization with maleic anhydride, methacrylic acid, and acrylic acid can introduce carboxyl groups.

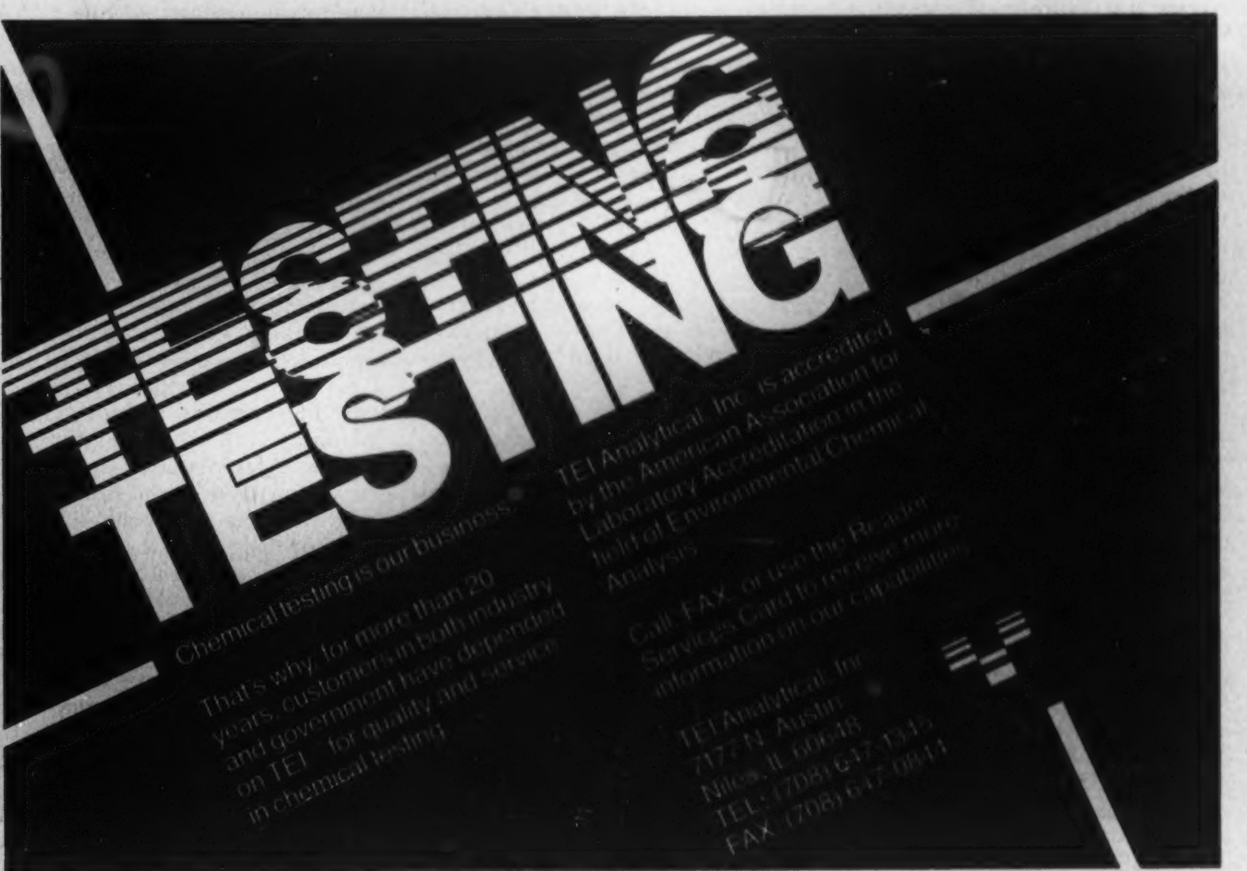
There are many manufacturers of specialty water-soluble polymers. They include most of the water treatment companies or their parent companies, and others, such as American Cyanamid, Rohm & Haas, and Dow, which have well-established positions in the water treatment polymer market. National Starch & Chemical Co. is the sole manufacturer of sulfonated polymers, primarily polystyrene sulfonate, for water treatment. Polymers are often blended with inorganic coagulants and flocculants in formulations. The complementary behavior of these materials as mixtures is sometimes not well understood, or remains a carefully guarded trade secret. Such mixtures can minimize the amount of metal hydroxides that would be formed with inorganic coagulants while offsetting some of the polymers' sensitivity to water conditions.

Cationic polymers also find some application but can be somewhat more expensive to produce. These can be acrylamide-based with a cationic monomer, or polyamines. Other cationic polymers are homopolymers of epichlorohydrin-dimethylamine or dimethyldiallylammonium chloride, or copolymers with acrylamide.

Two chemicals specifically labeled as water treatment chemicals and regulated under the Safe Drinking Water Act are acrylamide and epichlorohydrin. Eric W. Muchmore, business manager for water treatment chemicals in American Cyanamid's specialty polymers department, explains that either chemical could appear in water treatment polymer formulations if there is unreacted monomer from the production process. With careful control in manufacturing, EPA limits on residual acrylamide and epichlorohydrin can be met and maintained by monitoring product quality.

In a competitive and growing market, manufacturers of the specialty polymers hesitate to reveal the actual composition of their copolymers. Water treatment polymers are carefully designed to separate out finer particles, add weight to the floc, and stabilize the resulting sludge by keeping solids together. Different types of solids, resulting from chemical or paper manufacturing processes, require different polymer treatments. Biological sludges are particularly difficult to treat, notes Muchmore.

Product performance—the ability to produce sludges with lower water content and a higher percentage of solids—is very important. When initially formed, sludge from wastewater may be only a few percent solids, increased to around 20% after being dewatered. The mechanical properties of the sludge depend on the polymer used and affect how well the sludge can be dewatered on equipment such as belt filters and presses. "The polymer supplier who can show higher [sludge] cake solids," says Muchmore, "is the one who is going to win bids."



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"Every percent [of] water that is removed has significant impact," he says. "Millions of dollars in disposal and operating costs can be saved from a few percent change." The rising cost of transporting and disposing of sludges has become a major concern for both industry and municipalities. In the past, about 25% of sludge has been incinerated, explains Muchmore, and about 75% placed in landfills. Tighter regulations are being imposed on the water content and composition of sludges that can be disposed of in landfills. A ban on ocean dumping of sludges will also go into effect this year.

Many see incineration, which also requires sludges with a higher solids content for more efficient burning, as a viable option. The obstacles to incineration include restrictions on materials that can be burned and opposition to the construction and use of incinerators for waste treatment. Sludges containing hazardous wastes are regulated under the Resource Conservation & Recovery Act. Further regulations on sludge management and disposal will result from the 1987 amendments to the Clean Water Act.

Those amendments, guidelines on organic chemicals, plastics, and synthetic fibers, and the Safe Drinking Water Act regulations are changing how industry and municipalities will have to treat water and wastewater in the near future. Traditionally, wastewater treatment, particularly municipal, is a process to neutralize the water, separate solids, remove organics with biological treatment, disinfect, and control odors. Most of this treatment requires only a few commodity chemicals—alum, lime, caustic soda or soda ash, and chlorine. Commodity chemicals such as caustic soda, soda ash, and acids used for pH adjustment accounted for nearly 1.4 billion lb or about 11% of the total water treatment chemical volume in 1988, whereas 4.9 billion lb of lime were used. Chlorine and chlorine derivatives made up 85%, or 2.1 billion lb, of the market for disinfectants and oxidants in 1988.

When commodity chemicals alone are needed, they may be purchased directly from suppliers, rather than through water treatment companies. The water treatment companies will have increasing involvement in wastewater treatment as new technologies are needed to meet tighter regulations. A new market area targeted by Nalco is in providing consulting and product services on the biological treatment of wastewater. The needs in this area are twofold, explains Kaufmann. An optimum environment must be created for the microorganisms to grow and digest wastes and the desired organisms must be present to digest specific contaminants. This can involve "troubleshooting" to bring an activated sludge or aeration lagoon back into line and providing "formulations" of isolated, naturally occurring biological organisms. "If you can find a microorganism that will remove a particular organic, you can pretreat the waste stream before it hits the treatment facility and overloads the plant," says Kaufmann.

Stricter effluent guidelines under the Clean Water Act and drinking water standards under the Safe Drinking Water Act are setting limits between 1 mg per L and 50 ng per L on more than 100 organics, pesticides, and inorganics. On average, limits are now reaching well into the parts per billion, and even parts per trillion, range. In some cases, the technologies may not yet exist, or can be prohibitively expensive, to treat for certain materials or to reach the low levels proposed. Such methods are generally termed tertiary or advanced treatments.

One advanced treatment for the removal of organics is adsorption onto another medium. Although biological treatment can remove about 95% of suspended solids and of the biological oxygen demand, effluent levels of some organics may need to be lower. Activated carbon is considered the best available and most cost-effective technology under the Safe Drinking Water Act to adsorb organics in producing potable water. It can be used as a pretreatment to remove organics that may be toxic to microorganisms, or in combination with or following biological treatment to reach very low effluent levels. In industrial applications, it may be used for the removal of hazardous compounds, to improve water quality for reuse, or to meet pretreatment or discharge standards.

Computers are used to monitor and control water treatment

In 1988, $111 million worth, or 135 million lb, of activated carbon was used in water treatment. Activated carbon comes in two forms, granular and powdered, produced mainly by Calgon Carbon, American Norit, and Westvaco. Granular activated carbon is used in beds and columns whereas powdered carbon may be mixed with the water, then separated out by settling or filtration.

In the late 1970s, activated carbon producers expanded capacity in anticipation of regulatory measures for drinking water. However, the regulations were not enforced and a period of overcapacity resulted. "We believe now that the Safe Drinking Water Act amendments provide clear direction for where we are heading," says Roger Zanitsch, vice president, marketing and sales for Calgon Carbon. "One of the big growth areas of the 1990s will be water treatment." Final regulations on drinking water and groundwater, where activated carbon is used to strip organics, may affect activated carbon consumption.

"Any time specific organic chemicals in water are identified," he adds, "it favors the activated carbon technology." Activated carbon adsorbs most organics, but favors higher molecular weight compounds.

The carbon can be regenerated by thermally or chemically removing adsorbed materials. Calgon reprocesses activated carbon for its customers and sells directly to users and to contractors building water treatment facilities. The company also supplies the systems it builds for groundwater treatment.

The scale of the application will determine whether it is economically feasible to reprocess or replace the carbon. Typically, about 10% of the material is lost due to attrition and reprocessing, explains Zanitsch. In taste and odor control applications with low dose rates, it is cost-effective to replace the carbon every three to four years. Because of the low rate of adsorption for low molecular weight organics, other removal methods may be more cost-effective.

Thus activated carbon is not an effective method to remove trihalomethanes (THMs), such as chloroform, bromoform, bromodichloromethane, and dibromochloromethane. Final EPA regulations on THMs, suspected carcinogens formed by the chlorination of organics in water, are expected in the near future. Activated carbon is suggested as a way to remove their organic precursors.

Another approach to decrease THM concentrations is to relocate the point of chlorine addition in conventional processes to where the organic content is lower. After disinfecting with chlorine, water can be dechlorinated, to avoid reaction with naturally occurring organics, by dosing with sulfur dioxide as a reducing agent. Alternative disinfectants for drinking water are gaining attention as a means to prevent the formation of THMs and thereby avoid expensive treatment methods.

Possible replacement oxidizing chemicals include ozone, chlorine dioxide, organic halogen (Br and Cl) donors, sodium or calcium hypochlorite, and potassium permanganate. Each of the chemicals varies in effectiveness against contaminants, and consideration must be given with regard to handling, and to environmental and health issues. Although not forming trihalomethanes, other chlorinated organics may be formed with some chlorine derivatives. Despite being considerably more expensive than chlorine, many alternative disinfectants are expected to increase in use.

Hydrogen peroxide use is seeing growth as a replacement for chlorine in odor control, for removal of hydrogen sulfide and other sulfur compounds, and as a means to detoxify or destroy organic chemicals. In 1988, 62 million lb of hydrogen peroxide were used in water treatment, with municipal and institutional use accounting for 69% of use. The largest producers are FMC, Interox, Du Pont, and Degussa.

"For environmental applications—water, wastewater, and hazardous waste treatment—compounded annual growth rates are expected to exceed 10% per year through 1995," says Robert S. Kouk, development

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manager for the environment at Interox. Municipalities are a fairly mature market, where treatment consists of simple dosing with hydrogen peroxide to reduce odor. Hydrogen peroxide is generally sold as a raw material to users and may not require large capital or operating costs to implement its use.

Despite its reputation, producers indicate that it is stable, can be handled safely, and is reasonably cost-effective in light of advantages it may offer over other treatments. For example, in comparison to other treatment technologies that isolate, precipitate, or transfer the pollutant to an adsorbant, hydrogen peroxide can eliminate a pollutant completely with no residuals for disposal or reduce it to degradable levels. "Environmentally, it's one of the safest chemicals as it breaks down into oxygen and water," says Kouk, "and you can't say that about a lot of chemicals."

Theoretically, hydrogen peroxide can completely decompose organic compounds into carbon dioxide and water. The amount of hydrogen peroxide needed to complete this stoichiometric reaction may not be economically feasible, critics say. However, by using lesser amounts, organics can sometimes be decomposed into less toxic or more readily biodegradable by-products. Therefore, hydrogen peroxide can be useful as a pretreatment step before biological treatment to reduce toxicity, or as a tertiary treatment to remove remaining refractory organics.

Calgon photo

Specialty polymer filter system flocculates and separates solids

Producers look to the development of new hydrogen peroxide-based technologies for industrial waste treatment as an area with strong growth potential. Both FMC and Interox work with smaller companies to develop advanced treatment technologies based on hydrogen peroxide. These generally involve activating the hydrogen peroxide to more effectively break down organics, such as phenols, aromatics, and pesticides, which are coming under increasingly strict regulation by EPA.

"As the nature of the problems has gotten more complex," explains Randy Bull, manager of commercial development for FMC's Peroxygen Chemicals Division, "we've had to work at developing new and more complex technologies to address them." Hydroxyl radicals are produced in solution, a single radical can be created using a transition-metal catalyst. The oxidation reaction can be controlled or made selective to specific contaminants by changes in pH, temperature, concentration, retention times, and the presence of catalysts.

A newly developed technology employs an additional oxidant, such as ozone, and activation by UV light to produce two hydroxyl radicals and break down refractory organics. Hydrogen peroxide enhances the effectiveness of the ozone oxidation process, Bull says. "This technology is attractive since it does not require adding anything [but ozone and hydrogen peroxide] to the water." Hydrogen peroxide is also finding application as a source of dissolved oxygen in biological treatment and in bioremediation of groundwater.

Despite the growing need, questions still remain as to whether the technologies exist to deal with the stricter effluent and drinking water standards proposed by EPA. "The most recent regulations are going to have us treating water for the removal of contaminants or pollutants that we've never treated for before," says Robert Bates, vice president and south region manager with Hart Environmental Management of New York City. "Some of the chemicals that have traditionally been used and conventional processes may diminish in use as new technologies are developed," he says, "because they don't do a particularly good job in removing the contaminants of concern."

Complying with water quality standards will have an impact on municipal and industrial water treatment operations as EPA regulations go into effect in the next few years. With the organic chemicals, plastics, and synthetic fibers guidelines being upheld in March 1989, industry must comply with pretreatment standards in three years and with direct discharge regulations when permits are renewed. Meeting standards of parts per million or parts per billion levels on more than 100 contaminants will require the investment of time and money on the part of industry and public treatment facilities. Increased monitoring and specialized treatments for previously unregulated chemicals will be the responsibility of companies or municipalities discharging water. To service customers, water treatment and specialty manufacturers will need to invest in research and development to develop advanced treatment methods.

The guidelines are expected to affect 1000 plants, according to EPA. In challenging the guidelines, the Chemical Manufacturers Association and the Synthetic Organic Chemicals Manufacturers Association focused on the economic and technical feasibilities of meeting the proposed standards. The impact is expected to be disproportionately severe for smaller producers, which, without the economies of scale, may be put out of business. In 1987 when the guidelines were first issued, it was estimated that 60 plants might possibly be shut down and overall compliance costs would exceed $500 million. □

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National Institute of General Medical Sciences funds variety of chemical research Page 13

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CHEMICAL & ENGINEERING
NEWS
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News of the Week

- **Two U.S. chemical companies have refused to sell the Army a key precursor chemical needed to make the nerve gas Sarin.** Page 4
- **DOE studies possible buildup of flammable hydrogen gas in nuclear waste storage tanks at Hanford, Wash., facility.** Page 5
- **Under a new initiative from NSF, states will receive grants to promote reform in precollege science and math education programs.** Page 5
- **Study of 10 years of global temperature measurements collected by satellite shows no warming trend for Earth during the 1980s.** Page 6
- **Cetus and Genetics Institute have resigned from the Industrial Biotechnology Association, charging favoritism toward some member companies.** Page 6

Business

Many biotechnology firms enter the new decade with hefty revenue gains and increased product sales, but few show a profit because of R&D and operating costs. Page 9

Science/Technology

Rapid route to producing and screening antibody fragments is breaking new ground and may soon replace hybridoma technology in many applications. Page 18

Low-cost method for catalytic asymmetric epoxidation of unsubstituted olefins has been developed by chemists at the University of Illinois, Urbana-Champaign. Page 20

Books

"Ozone Crisis" by Sharon L. Roan is a successful history of ozone depletion and the chlorofluorocarbon controversy, but falls down on reasons for lag time in response; "Dust Explosions" by W. Bartknecht is an up-to-date reference for those concerned with producing, storing, or transporting dusts. Page 21

ACS News

The society recently expressed views to the House on changes to laws governing disposal of hazardous wastes as well as on the need for more funds for fossil energy R&D. Page 24

Government

National Institute of General Medical Sciences, source of most NIH chemistry research funds, reassesses priorities under tighter funding policies. Page 13

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LETTERS

CHEMICAL SAFETY

Alkylaluminum fluoroalkoxides

SIR: In recent years, Texas Alkyls has been interested in organoaluminum compounds containing heteroatoms. Alkylaluminum compounds containing haloalkyl groupings were of particular interest because of their potential as catalyst modifiers in Ziegler-Natta olefin polymerization. Brian L. Goodall first reported an alkylaluminum fluoroalkoxide in 1981 at a symposium on transition-metal-catalyzed olefin polymerizations. Goodall described the effect of diethylaluminum 2,2,2-trifluoroethoxide (DEAL-FE) on model systems for Ziegler-Natta catalysts.

A variety of alkylaluminum fluoroalkoxides, including DEAL-FE, was synthesized at Texas Alkyls and tested as cocatalysts in olefin polymerization over a period of two years without incident. Preparations sometimes included purification via vacuum distillation at temperatures up to about 100 °C. Recently an explosion occurred in a syringe needle when one of our chemists was transferring a small quantity of DEAL-FE. Fortunately, because he was wearing the appropriate safety gear (face shield, fire-retardant lab coat, and gloves), the chemist was not injured. Subsequent to the incident, storage containers of alkylaluminum fluoroalkoxides at Texas Alkyls were checked for signs of decomposition. All containers, originally under a nitrogen pad of ≤ 3 psig, showed pressures of 40 psig or more after having been stored for several months, indicating slow decomposition even at ambient temperature.

Tests were conducted to investigate causes of the incident. Results showed that neat DEAL-FE begins to undergo slow, exothermic decomposition at about 75 °C. Above 100 °C, decomposition occurs violently. The power of neat DEAL-FE decompositions was found to be comparable to that of explosives. Further, the tests showed neat DEAL-FE to be shock sensitive. A 25% solution of DEAL-FE in heptane was subjected to the same battery of tests. The solution did not decompose violently on heating to about 190 °C, nor did it show shock sensitivity.

We urge that alkylaluminum fluoroalkoxides be produced only as dilute ($\leq 25\%$) hydrocarbon solutions. Extreme caution should be used to ensure that such solutions are not concentrated in the course of handling to avoid the possibility of explosion from exposure to high temperatures or shock.

D. B. Malpass
Texas Alkyls Inc., Deer Park, Tex.

Ammonia does burn

SIR: The letter by Ernest J. Tews (C&EN, Jan. 15, page 2) highlights a problem with the meaning of familiar terms as defined in dictionaries of common usage, as used every day in ordinary speech and writing, and as defined technically. Whether or not ammonia is nonflammable or not depends on how the term is defined.

The term combustible is the most basic adjective relating to burning behavior. As defined by Webster (1979), and over the past 40 years or so, combustible applies to any material that "undergoes oxidation accompanied by the evolution of heat and light"—namely, any material that ignites and burns. Neither burn nor combustible implies a rate of reaction.

The word flammable, however, does imply a rate, and a flammable material is any combustible material that is "capable of being easily ignited and of burning with extreme rapidity." Conversely, a nonflammable material is "one that is not easily ignited and does not burn rapidly if ignited." To that extent ammonia is nonflammable. Of course, these definitions assume normal atmospheric conditions, not oxygen-rich or high-temperature environments such as mentioned by Tews.

Unfortunately, in popular usage flammable and combustible are more and more being used as synonyms, as are nonflammable and noncombustible, so that eventually the dictionary distinction between the meanings of the terms will be lost. This is reflected in Tews' letter.

To complicate matters, the wording used by the U.S. Department of Transportation to classify materials that are hazardous, primarily because of their burning behavior, does not follow either popular usage or dictionary definitions. In the Code of Federal Regulations (49 CFR 172.102) the burning behavior of materials is classified for labeling pur-

Correction

- March 12, page 19: Plastics contribute 3576 tons of lead to municipal solid waste streams, not 320 million tons.

Many Biotech Companies Enter '90s With Sharply Higher Revenues

Increased product sales are leading to hefty revenue gains, but with R&D and operating costs still high few firms reported profits for 1989

Ann M. Thayer,
C&EN Northeast News Bureau

With the start of a new decade, the health of the biotechnology industry in the 1990s is a topic of much speculation. If the close of the past decade is any indication, the industry is moving slowly toward profitability. Revenues in 1989 were up sharply for many biotechnology companies, with increased product sales contributing more significantly to income. However, the industry as a whole is not yet showing a profit.

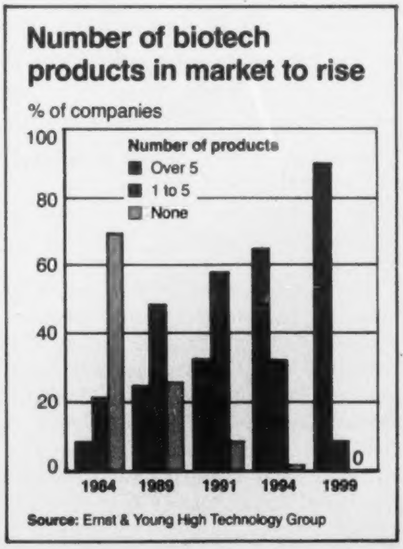
According to a 1989 survey of nearly 500 biotechnology companies by Ernst & Young, a San Francisco-based consulting firm, only about one fourth of biotechnology companies are reporting net profits. But, more than 50% of all companies are seeing some improvement in performance in terms of smaller losses or larger profits than in previous years.

Similar trends are observed in a group of 35 companies sampled by C&EN. Combined 1989 revenues totaled slightly more than $1.2 billion, an increase of 33% over 1988. In addition, in 1989, these companies reported a combined loss of $175 million. Larger companies, including Amgen, Biogen, Collagen, and Genentech—with a few major products among them—saw the greatest increases in revenues and earnings. For some companies reporting a net income, 1989 marked the first year of profitability.

Sales account for about two thirds of revenues for those companies marketing products. Total sales reached nearly $600 million in 1989 for 20 of the 35 companies reporting product sales. This 53% increase over 1988 sales is higher than the industry average of 33% growth in sales from the survey by Ernst & Young, which determined that 74% of all companies have product sales.

Contract research and collaborative R&D agreements provide the second most significant source of revenue for most companies. R&D spending averages 63% of sales in the biotechnology industry. Biotechnology companies in the area of therapeutics and agriculture can easily have R&D expenses at levels of more than 100% of sales. The norm for R&D spending in the pharmaceutical industry is 16% of sales.

Analysts predict that the 1990s will bring an increased flow of major biotechnology products. Introducing at least one new, and often a first, product is the goal of most companies in the near future. As many companies approach the final stages of product development and preparation for marketing, expenses increase markedly and earnings can drop dramatically. Cetus reported a net loss of more than $55 million in 1989, in preparation to launch its interleukin-2 product, which is awaiting Food & Drug Administration approval. Genetics Institute reported a net loss of nearly $29 million from delays in an anticipated licensing agreement, costs in preparing to market its erythropoietin (EPO) product awaiting FDA approval, and a contractual dispute related to EPO production. EPO is a protein that stimulates the production of red blood cells and is used to treat anemia.


Number of biotech products in market to rise

Source: Ernst & Young High Technology Group

EPO was approved for sale in June 1989, but premarketing expenses in the first half of the year offset Amgen's nearly $100 million in sales of the product. The company reported modest net earnings for 1989 and is facing a forced cross-licensing agreement with Genetics Institute on EPO in 1990 (C&EN, March 19, page 9). The company probably will continue to face high costs in preparation for the launch of its next big product, a granulocyte colony stimulating factor used for the production of white blood cells.

One biotech company well on its way is Genentech, of Thousand Oaks, Calif. With just two products, Genentech accounted for more than half of 1989 product sales for the 20 companies reporting sales. The company led the industry with $196 million in sales for Activase, the blood clot dissolving agent tissue plasminogen activator (TPA), and with $123 million in sales for Protropin, a human growth hormone. Despite being the largest and most profitable of companies, Genentech sent shock waves through the biotech-

Few biotech companies were profitable in 1989

$ Thousands	Revenues[a]	Earnings	Change from 1988		Profit margin[b]	
			Revenues	Earnings	1989	1988
Amgen	$155,729	$3,759	103%	191%	2%	2%
Applied Biosciences	57,690	4,930	86	31	9	12
Biogen	40,894	3,214	35	def	8	def
Biotech Research	17,112	1,485	4	−1.4	9	9
Calgene[c]	32,012	−6,574	25	def	def	def
California Biotechnology	15,832	−8,217	−6	def	def	def
Cambridge BioScience	8,572	−8,478	94	def	def	def
Calgene	2,753	−5,219	24	def	def	def
Centocor	76,963	115	22	−85	0.2	1
Cetus	28,704	−55,781	−16	def	def	def
Chiron	40,653	−21,629	15	def	def	def
Collagen	51,998	3,624	37	212	7	3
Crop Genetics	2,979	−6,053	−6	def	def	def
Cytogen	7,468	−13,956	27	def	def	def
Damon Biotech	5,997	−3,058	2	def	def	def
DNA Plant Technology	12,890	−2,948	60	def	def	def
Ecogen	2,939	−8,179	−55	def	def	def
Enzo Biochem	20,387	−4,382	63	def	def	def
Enzon	7,726	−3,563	166	def	def	def
Genentech	400,455	43,961	20	114	11	6
Genetics Institute	43,644	−28,737	47	def	def	def
Genzyme[d]	34,285	−5,704	33	def	def	3
Immunex	28,166	−6,979	27	def	def	3
Immunogen[e]	367	−3,727	−5	def	def	def
Integrated Genetics[f]	13,591	3,824	87	def	28	def
Liposome	3,761	−7,620	−16	def	def	def
Molecular Genetics	4,609	952	66	def	21	def
Mycogen	10,179	−1,403	74	def	def	def
Praxis Biologics[g]	11,971	−7,530	128	def	def	def
Repligen	12,044	−1,589	45	def	def	def
Ribi ImmunoChem	1,240	−2,891	−4	def	def	def
Synbiotics	7,194	−5,049	−5	def	def	def
Synergen	14,796	−1,311	103	def	def	def
T Cell Sciences	10,991	−1,203	55	def	def	def
Xoma[h]	19,230	−18,878	32	def	def	def

a Includes sales, contract research, royalty, and interest revenues. b After–tax income as percentage of sales. c Consolidated figures to include merger with Ingene in November 1989. d Third– and fourth–quarter results include acquisition of Integrated Genetics. e Results for two quarters after going public in August 1989. f Results for first and second quarters before being acquired by Genzyme. g First three quarters, acquired by American Cyanamid in November 1989. h Consolidated figures to include merger with Ingene in November 1989. def = deficit.

nology and financial communities when it decided it was necessary to sell a 60% interest to Roche Holding Ltd, whose main operating arm is Hoffmann-La Roche, the large Swiss chemicals and pharmaceutical firm.

Roche's investment will allow the company to operate independently while providing it with $492 million in capital to expand R&D efforts. An investment of this size effectively removes Genentech from having to respond to public financial markets, allowing it to focus on long-term R&D efforts. Although the company is marketing two major products, Activase is expected to receive very stiff competition in the coming years from less expensive drug treatments.

For most companies, sources of financing remain the major concern. According to the Ernst & Young survey, 62% of all companies will need major financing of a few million dollars each by the end of 1990 and 90% will need financing by the end of 1991. For some companies the problems are imminent: 59% of small companies, 35% of mid-size, and a few percent of large companies will survive less than 12 months without immediate financing.

In general, companies seek support from three sources—public equity markets, R&D or manufacturing alliances with large companies, and mergers. Cash flow problems affected several companies in 1989 and are leading to what some believe are the first stages of consolidation in the industry. Bio Response, Hayward, Calif., unable to find the cash to cover $22.4 million worth of debentures tendered in 1989, declared bankruptcy in September. The company, which produces proteins by mammalian cell culture methods for use in therapeutic drug products, was acquired for $9 million by Baxter Healthcare, the U.S. operating subsidiary of the large Baxter International health care company.

Large pharmaceutical companies can use an acquisition of a smaller company as a means to obtain an established technology and enter the biotechnology arena. As is often the case, a relationship between the biotechnology and pharmaceutical company may already exist. The recent acquisition of Damon Biotech, Needham Heights, Mass., by Abbott Laboratories for $9.4 million is an example. Damon Biotech had agreed to produce genetically engineered urokinase, a competing drug with TPA, for Abbott. In April 1989, the company reported it had sufficient cash to operate for about 12 months and expressed concern about future cash availability.

Similarly, American Cyanamid acquired Praxis Biologics, Rochester, N.Y., in November 1989 in an exchange of $238 million worth of shares. Praxis reported losses of more than $7 million in both 1988 and 1989. However, the company had product sales of more than $8 million on its Hibtiter vaccine for bacterial meningitis, one of the first biotechnology drugs to receive FDA approval. The company was seeing lower than expected sales, increasing competition, and high costs in bringing its second product to market.

Not all acquisitions or mergers have been among large pharmaceutical and smaller biotechnology companies. Calgene, based in Davis, Calif., and one of the larger agricultural biotechnology companies, acquired its neighbor and rival, Plant Genetics, in a $12 million stock transaction completed in July 1989. Mycogen, San Diego, Calif., another rapidly growing agricultural biotechnology company, bought the commercial and agricultural products division of Safer for an investment of $5.5 million. In the area of therapeutics, Xoma, Berkeley, Calif., acquired Ingene in November. Genzyme, Boston, merged with Integrated Genetics, Framingham, Mass., in mid-1989. Mergers are being used increasingly by biotechnology companies as a means to expand resources in their push toward marketing products.

Unlike the acquisition of a biotech firm by a large, capital-rich pharmaceutical company, acquisition of one biotechnology company by another can strain finances and often requires betting on future prosperity. For instance, Calgene and its newly acquired subsidiary, Plant Genetics, reported increased revenues but a net loss for 1989. The company expects a loss through 1990 with the continuing costs of product development and increased operating expenses after the merger. Having raised $27 million in an August 1989 stock offering and established a $10 million credit agreement early in 1990, the company plans to expand field trials of its herbicide-resistant crops.

In a move to raise at least $15 million in capital to bring its products to market, Ecogen, an agricultural biotechnology company based in Langhorne, Pa., recently appointed an investment banker to investigate the sale of all or part of the company. The company predicts bankruptcy in the next six months if new capital is not brought in. Ecogen has two biopesticide products that have received EPA registration, a third product nearing approval, and several more under development. The company lost more than $8 million in 1989 on decreased revenues of $2.94 million.

Product sales are major part of 1989 revenues

$ Thousands	Product sales	Change from 1988	% of revenues	R&D costs	R&D as % of sales
Amgen	$ 99,427	3825%	64%	$ 63,166	64%
Biogen	24,725[a]	28	61	28,486	115
Calgene[b]	21,808	25	68	11,283	52
California Biotechnology	1,006[a]	-84	6	14,858	nm
Centocor	27,616	25	36	45,354	164
Cetus	4,468[a]	134	16	50,000[c]	nm
Chiron	4,934	304	12	46,100	934
Collagen	45,315	44	87	14,099	31
Crop Genetics	2,051	5	69	5,361	261
DNA Plant Technology	161[a]	164	1	11,985	nm
Genentech	319,000	22	80	159,000	50
Genetics Institute	na	—	—	59,426	na
Genzyme[d]	23,753	26	69	na	na
Immunex	4,276[a]	142	15	18,889	442
Liposome	54[a]	-78	1	8,027	nm
Molecular Genetics	120	199	3	2,229	nm
Mycogen	955	449	9	7,842	821
Praxis Biologics[e]	8,243	3335	89	8,456	103
Ribi ImmunoChem	728	23	29	1,794	246
Synbiotics	4,452	90	62	5,410	122
T Cell Sciences	3,336	24	30	na	na
Xoma[f]	na	—	—	25,617	na
TOTAL[g]	$569,140	53%	62%	$488,522	88%

a Includes royalties and licensing fees. b Consolidated figures for the year to reflect merger with Plant Genetics in July 1989. c C&EN estimate. d Last six months of year include acquisition of Integrated Genetics. e First three quarters, acquired by American Cyanamid in November 1989. f Consolidated figures for the year to reflect merger with Ingene in November 1989. g Totals and percentages for companies reporting both sales and R&D costs. nm=not meaningful, percentage greater than 1000. na=not available.

More recently, in mid-March Ecogen disclosed two investments in the company. One was a sale of $1.5 million worth of stock to a single private New York investor. The other was a sale of $500,000 worth of stock and the awarding of exclusive distribution rights for its biopesticides in Taiwan to Jia Non Enterprises. Over seven years, the Taiwanese company will pay Ecogen up to $2.7 million in royalties and has the option to purchase another $500,000 in shares.

With its acquisition of Ingene, Xoma reported a net loss of nearly $19 million in 1989 resulting from increased expenses and its push toward commercialization of two products based on monoclonal antibodies. In April 1989, Xoma raised $57.5 million on an issue of debentures redeemable in 2014. The company has applications pending with FDA for approval of Xomen E5, used to treat gram-negative sepsis, and Xomazyme H65, used to treat graft versus host disease in bone marrow transplants.

Companies with successful product launches may become self-sustaining companies in the future and find public markets more willing to invest. A long-stated goal of biotechnology companies has been to operate as independent, vertically integrated biopharmaceutical firms. Most companies currently rely on manufacturing alliances to market their products.

One company that has successfully used its strategic alliances is Biogen, based in Cambridge, Mass. The company has developed at least five major biotechnology drugs and has licensed them to large worldwide pharmaceutical manufacturers for marketing. In 1989, the company reported its first profitable year. However, in light of industry goals, companies will have to balance short-term cash returns with long-term commitments to outside companies. An increased number of strategic alliances throughout the 1990s, concludes Ernst & Young, may lead to a smoother consolidation of the biotechnology industry in the future. ☐

Chemical Research Funding Hit By Tight Budgets At NIH

National Institute of General Medical Sciences, source of most NIH chemistry research funds, changes priorities under new funding policies

Pamela S. Zurer, C&EN Washington

At the National Institutes of Health, most research funding for chemists comes from the National Institute of General Medical Sciences (NIGMS). In fiscal 1988, for example, NIGMS awarded $86 million to departments of chemistry—71% of total NIH funding for chemistry and not a whole lot less than the amount supplied by the National Science Foundation's chemistry division. It's no surprise, then, that chemists are worried that NIGMS, like the rest of NIH, is facing severe budget constraints on the number of new grants it can fund.

Given a budget that has been just keeping up with inflation, large commitments to continue funding ongoing grants, and the escalating cost of the average grant, the number of approved applications that NIGMS can support has plummeted.

"For most of the '70s and the '80s, NIGMS funded close to 40% of approved applicants," says the institute's deputy director Marvin Cassman. "Last year [fiscal 1989] it was 29%, and this year our projected value is 23% and may well turn out to be lower. That's one chance in five for all applications coming into the system. For certain categories of applications there's an even poorer probability of success.

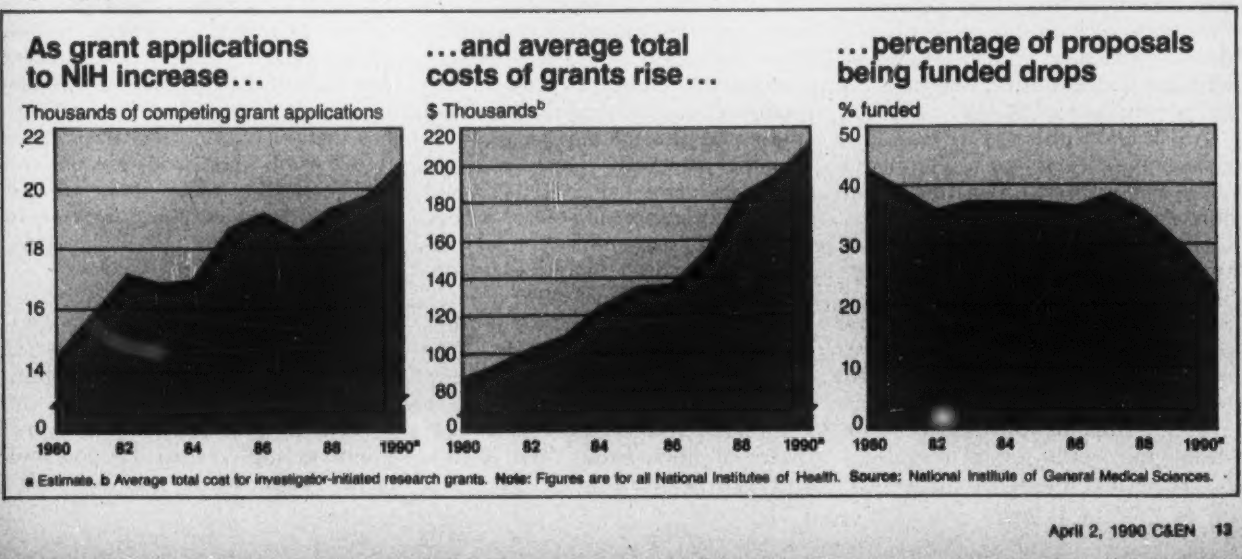
"There's always a line that you draw when you run out of money. And the people on one side of that line are very close to the people on the other side. But for the first time, the people on the wrong side of the line are almost as good as the best people we're funding. That's very hard to take."

NIGMS is responding to the problems caused by extremely tight money by implementing three new policies. The National Advisory General Medical Sciences Council, which sets policy for the institute, decided at its January meeting that NIGMS staff should—in certain cases—consider factors other than scientific merit in making funding decisions.

The staff has been instructed to give special consideration to highly rated applicants who have no other source of research funds. At the other end of the scale, applications from researchers whose total grant support exceeds $500,000 will be given extra scrutiny. And renewal applicants will generally be held to a 10% increase in budget over their previous grant.

"We're not happy about having to do any of these things," Cassman says. "It's a question of how to assess our priorities when faced with a situation where the grants that we are not funding are almost as good as the best grants that we are funding."

NIGMS's support for chemistry research is substantial, but pinning down its exact extent is difficult. The figures for money awarded to departments of chemistry represent a minimum, for much of the chemical research underwritten by the institute is carried out in departments



As grant applications to NIH increase...

...and average total costs of grants rise...

...percentage of proposals being funded drops

a Estimate. b Average total cost for investigator-initiated research grants. **Note:** Figures are for all National Institutes of Health. **Source:** National Institute of General Medical Sciences.

of biochemistry or molecular biology or in medical schools.

"If you include in your definition of chemistry every research area set out in the National Academy of Sciences' report 'Opportunities in Chemistry,' that would account for practically the entire institute's budget," Cassman says. In fiscal 1989, the institute spent more than $541 million on research project grants and expects to give out about $561 million in fiscal 1990.

The bulk of NIGMS's funds that go to chemistry as it is more traditionally defined spring from three administrative areas within the institute: the pharmacological sciences program, the cellular and molecular basis of disease program, and the biophysics and physiological sciences program.

The focus at NIGMS is very different from the other NIH institutes, which specialize in specific diseases or organs. NIGMS's goal is to support the basic research that underpins other health-related investigations.

"Our director's philosophy is that we support investigator-initiated research in many areas, as long as it's good science," says Christine Carrico, director of the pharmacological sciences program. "We're a basic science institute and generally the direction the research is going to go is determined by what the scientific community is doing."

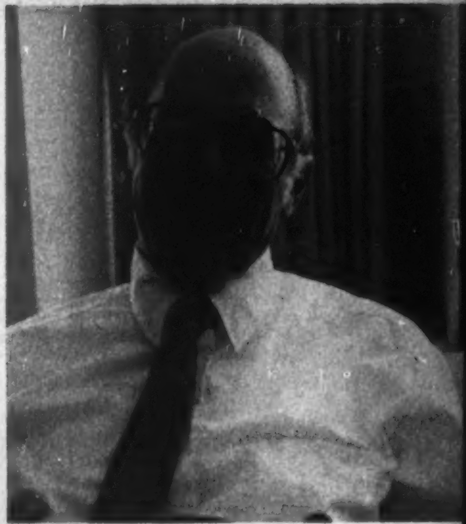
Adds Michael Rogers, scientist administrator in the same program: "We try to pick out the science that's the best and fund that, regardless of whether it's chemistry, pharmacology, genetics, or whatever."

About two thirds of pharmacological sciences' funds go to biorelated chemistry projects. "We fund a sizable amount of organic chemistry, including organic synthesis, total synthesis, reaction methodology, and natural products chemistry," Rogers says. "We also have a big portfolio of inorganic chemistry, looking at metallochemistry related to metalloproteins and metalloenzymes." The program also funds a sizable number of grants in molecular recognition, biomimetic-type chemistry, artificial enzymes, photochemistry, and peptide and nucleic acid chemistry.

The pharmacological sciences program also has an anesthesiology branch, which supports research into the molecular mechanisms of how anesthetics act, as opposed to general whole-organism studies.

"The only real restriction—and that is also not a hard and fast one—is that the research has to be biologically related," Carrico says. "There are probably a few grants we support where you have to go through some mental gymnastics justifying the biological relevance, but by and large because it's NIH the research we support should be biologically related."

Last year the pharmacological sciences program put out a specific request for grant proposals in basic chemistry in support of acquired immune deficiency syndrome-related studies, an unusual move at an institute that generally does not solicit proposals. However, NIGMS had been given a specific pool of money to fund fundamental chemical research that could benefit development of drugs against AIDS.



Cassett (left): training programs vital. Cassman: one-in-five funding chance. Jones: competing pool is shrinking

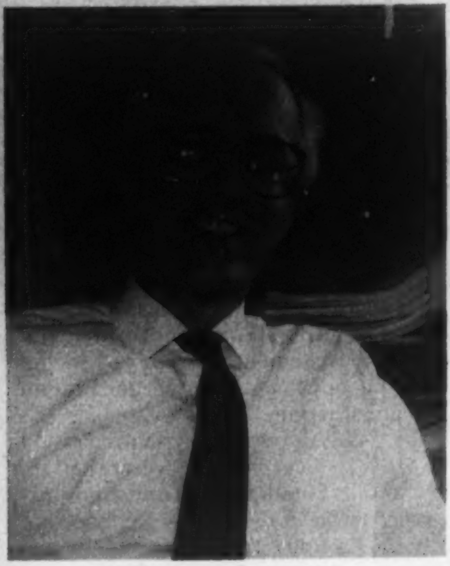
Among other areas, the request for AIDS-related applications suggested such research fields as chemistry for linking small molecules to natural macromolecules, chiral synthesis of nucleosides, and design and synthesis of selective DNA cleaving compounds. The institute received close to 50 applications by the Dec. 1 deadline and expects to fund seven to 10 grants with a total cost of up to $1.5 million.

Another NIGMS unit that funds a significant amount of chemistry is the molecular section of the cellular and molecular basis of disease program. About one quarter of the 365 grants that section is funding this year support investigators in chemistry departments. Another third goes to biochemistry departments.

"A lot of work that is supported through this program is concerned with catalysis, mechanisms of enzyme action, regulation of catalytic properties, metabolic transformations, and metabolic pathways," says Warren Jones, chief of the molecular section.

Much of the rest of the research his section supports could also be called chemistry, Jones says. "When all is said and done, every process that sustains life is based on chemistry," he points out. "This institute has historically and steadfastly said it will try to fund good research and not be terribly picky about what it is. We've had a very catholic view of what we'd support. The criterion is: 'Is it good science?' "

In the biophysics section of NIGMS's biophysics and physiological sciences program, 266 out of 582 grants, totaling about $36 million, are in chemistry departments, according to James Cassatt, the program's acting director. "If you look at the subject matter and ask what's



different about our grants that go to chemistry departments as opposed to biology or molecular biology departments, the answer is 'not much,'" he says.

Among the research areas the biophysics program supports are analytical chemistry and spectroscopic techniques. It also funds research into the biophysical properties of nucleic acids and proteins.

Other sections of the biophysics program support x-ray crystallography and analysis of proteins, nucleic acids, and related model systems by NMR. The NMR unit was created just a few years ago in response to progress in the field.

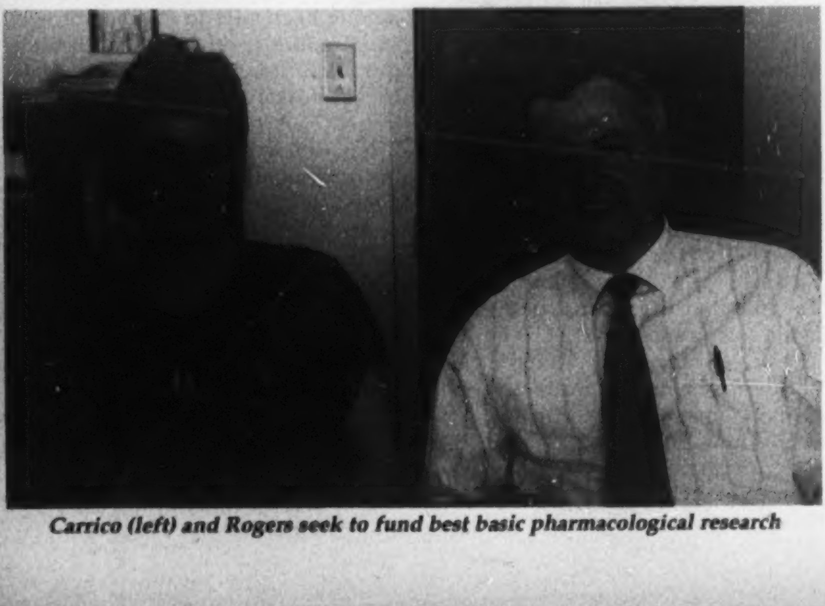
The biophysics program that is most dominated by chemist-investigators supports theoretical studies of proteins and nucleic acids. "These people are doing very fundamental studies," Cassatt says. "You'd find very few molecular biology departments that would house people like these—they are hard-core chemists."

In addition to its research grants, the biophysics and physiological sciences program administers a new training fellowship that draws heavily from chemistry departments. "It became clear a few years ago that there were insufficient numbers of structural biologists," Cassatt adds. "That is, people trying to understand the relationship between biologically important macromolecules and disease states.

"The whole area of computer-aided drug design really began with an understanding of structural biomolecules. It also appeared to be a fruitful area for investigating possible therapies for AIDS. But all this depends on the ability to train people in structural biology."

In designing the new training program, NIGMS encouraged universities to draw from pools of students beyond traditional biology departments. The fellowships are now supporting more than 200 trainees at 27 schools that have set up interdisciplinary programs.

"Some of our most successful programs have tried to attract people from chemistry departments, physics departments, and even math and engineering departments," Cassatt says. "These are students who traditionally have had the kind of quantitative training that's necessary for success in structural biology. They may be weak on biology, but it's our feeling that—with many exceptions—it's easier to take someone in the quantitative sciences and teach them biology than vice versa."



Carrico (left) and Rogers seek to fund best basic pharmacological research

All the NIGMS programs are facing the same tight funding squeeze. Once money is set aside from the current year's budget to pay for the ongoing grants that were previously funded (so-called noncompeting applications), there is little left for new grants (competing applications).

In fiscal 1988, NIGMS was able to fund slightly less than 1000 competing grants. In fiscal 1989, that number dropped to about 760 and is expected to decline further to about 630 this fiscal year.

"That's what's got everybody so discouraged," Jones says. "The pool of money has been growing a bit over that period but the additions to the budget have gone primarily to cover inflation. Our total number of grants is holding roughly constant, but because we were very successful in putting out new grants in the mid-1980s, it means that if the total pool doesn't grow the competing pool has to shrink."

Thus, the award rate for those applying to NIH for funds for the first time is much worse than the overall award rate of roughly 20% in fiscal 1990. Renewal applications inevitably have a better shot, according to deputy director Cassman.

"Renewal applications are all prescreened," he notes. "They were funded once already and that means somebody thought they were pretty good to begin with. Historically, they have always had a better probability of success. It used to be about 50%, but now it's about 30%."

Applications from investigators with no track record are the ones that are really suffering, according to Cassman. Those grant proposals often are from young researchers just beginning an independent career.

Cassman says it is not surprising or even undesirable that the peer-

National Institute of General Medical Sciences' budget is only keeping pace with inflation

$ Millions	1991[a]	1990[a]	1989[b]	% change 1990–91
Genetics	214.8	208.6	209.5	3%
Cellular and molecular basis of disease	204.6	193.9	189.8	6
Biophysics and physiological sciences	151.8	144.5	133.4	5
Pharmacological sciences	103.5	99.2	92.5	4
Minority biomedical research support	32.3	29.8	28.1	8
Minority access to research careers	13.4	10.7	9.1	25
Research management, other	25.1	25.4	21.5	−1
TOTAL	**745.5**	**712.1**	**683.9**	5%

Note: Programs that provide major support for research in chemistry departments are printed in color. a Estimate. b Actual. **Source:** National Institute of General Medical Sciences

review system favors renewal-grant applicants. People who have done well in the past will inevitably have an edge. The discrepancy was less painful, however, when there was enough money to fund both groups reasonably well.

"The best estimate I can get for applications coming in from first-time applicants—primarily young investigators starting out—is an award rate on the order of 11%," Cassman says. "That is an outrageously low number.

"What that means is the odds for a kid coming into his first academic position who is starting up a laboratory are a little better than one in 10. All things considered, the universities might be better advised to take the money that it costs in time and effort to send in a proposal, give it to whoever is applying, and tell him to go to Las Vegas. The odds are probably better than 10-to-one there."

Another group of applicants suffering from the low-award rate is made up of established investigators running small laboratories that get by with only one grant, according to Cassman. That practice was more common before many researchers began hedging their bets by having multiple grants, but many good scientists have not chosen to expand.

The first of the NIGMS advisory council's three recent recommendations is designed to address the crisis facing those two groups of applicants. It suggests that, given two proposals of similar merit, NIGMS should give preference to investigators with no other sources of support. That means that applications with better priority scores—the numerical ranking given proposals by peer reviewers—could be passed over in favor of ones that scored not quite so well.

Cassman explains, however, that all the applications in the range of priority scores affected are so good that differences of a few points are not really meaningful anyway. "We are now cutting off funding within a group of such high quality that it's extremely difficult to measure any difference between one grant and another," he says.

"We felt and our council felt that if we didn't protect not only the younger investigators, to allow them entry into the system, but also high-quality smaller laboratories, we'd lose something significant in the breadth of research that we can support."

The second NIGMS council recommendation is that the staff look very carefully at applicants that have more than $500,000 in support from any source. The impetus behind this policy is that large laboratories often have the wherewithal to spin off projects from existing grants.

"We have gotten applications where, although the proposal was evaluated as outstanding, it wasn't all that different in its target from another, already funded project," Cassman says. "It was another system, another organism, another enzyme of a similar kind. The question is: Do we want to fund another one of those as compared to a new application from a new investigator?"

The new policy in part reflects a recognition by NIGMS of the concern shown by a few of the NIH study sections (peer-review groups), according to Cassman. Study sections are supposed to judge only the quality of science in a proposal, not make funding decisions. Lately some have taken it upon themselves to do both, distorting the system in Cassman's opinion.

"We have had a few recent applications, which would have been outstanding in a normal review process, where the study section gave terrible priority scores," he says. "They said straight out in the summary statement of their report that [the applicants] were getting too much money."

"We are being very cautious about this [policy] because we are talking about outstanding investigators," Cassman adds. "Secondly, we don't like to tinker with peer-review decisions that aren't at the margin, which is what we were talking about in the first set of recommendations. But I think the council felt that given the circumstances we have no choice. It's an issue of equity."

The last advisory council recommendation involves budget increases for ongoing grants that have come back for renewal after peer review, known as competing continuations. With one exception, increases are to be held to 10%, plus whatever equipment is required.

The exception to the 10% ceiling is for first-time reapplicants who are eligible for renewal after their first grant. "Very often first renewals are an opportunity for an investigator to expand to a reasonable level after having been held to a comparatively small dollar level," Cassman points out. "We don't want to eliminate the opportunity for people really to get a foothold in their field."

NIGMS is moving very gingerly in implementing these new policies aimed at equitably distributing the pain of insufficient funds. "Obviously we need to examine the effects and consequences," Cassman says. "But we are putting them in effect now because, to be quite honest, there are people who can't wait for next year. They're going to die if they don't get their money now. And let me assure you, there are a large number of people for whom we can do nothing that I feel even worse about." □

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APRIL 9, 1990

CHEMICAL & ENGINEERING

NEWS

Top 50 chemical production grew only marginally last year
Page 11

Space Telescope

Instrument, soon to be launched, will yield new view of universe

Page 4

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NEWS

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APRIL 9, 1990

News of the Week

- **DOE, which is seeking to formulate a national energy strategy this year, releases report summarizing issues and comments raised in hearings around the U.S.** **Page 6**
- **1st Annual Conference on Cold Fusion held recently in Salt Lake City indicates cold fusion is still alive, although many remain skeptical.** **Page 6**
- **Senate passes Clean Air Act that pleases neither environmentalists nor industry; lobbying efforts now focus on House.** **Page 7**
- **Conoco to buy 400 houses and residential lots to settle suit by residents of Ponca City, Okla., who claimed groundwater contamination by hydrocarbons from company's oil refinery.** **Page 7**

Business

Top 50 chemical production edged up only 0.2% in 1989, just past the 1988 all-time high, to a new record of 611 billion lb. **Page 11**

Overall output of polymers—plastics, synthetic fibers, and synthetic rubber—slipped 2% last year, the first decline in seven years. **Page 14**

Government

Transport of food products and chemicals back-to-back in same vehicles would be prohibited by House legislation approved last month. **Page 17**

Yale protein chemist may head inquiry that is being set up by NIH into events leading to discovery of AIDS virus. **Page 18**

Science/Technology

Density-functional theory gains following among chemists as it improves quantum chemical calculations of large molecules, transition-metal compounds, organometallics. **Page 22**

Cover: Hubble Space Telescope during preflight testing at Lockheed Missiles & Space Co. Photo courtesy of NASA

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Cover Story

Hubble Space Telescope, to be launched from space shuttle scheduled to blast off on April 10, is first of four "great observatories" to be launched by NASA; several instruments making chemically related measurements are included in the package. **Page 4**

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LETTERS

Remembering Bill Bailey

SIR: I was shocked to read of the untimely death of Bill Bailey (C&EN, Jan. 1, page 7).

I, too, was an undergraduate student at the University of Maryland and remember Bailey well. In the early 1950s I was a student in his sophomore organic class, an assignment he had recently taken over from Nathan Drake. I recall very well the help he provided in getting a drowning organic student back on track. During 29 years of teaching organic chemistry to students at Ohio University, I have often confessed my initial difficulties with the subject and how vital it had been for me to take the initiative to get some help from the instructor. I know that my understanding of the troubles students encounter can be traced in part to my own experience, and that Bill Bailey's concern for me then has influenced greatly how I have dealt with students over these years.

I remember too the very special twinkle in his eyes as he discussed chemistry with me, indicating not only his love for the subject, but also the special, good-natured way he worked with people. He will be greatly missed.

Robert R. Winkler
Department of Chemistry
Ohio University

NSF chemistry grants

SIR: Janice Long and Pamela Zurer are to be commended for trying to find a silver lining in the storm clouds when they describe the 1991 budget request for the National Science Foundation's chemistry division (C&EN, Feb. 12, page 11): "The new budget request is . . . lower than that submitted for fiscal 1990. Still, the chemistry division manages to fund about 58% of the proposals it receives." Unfortunately, the silver lining is an artifact of the bookkeeping terminology NSF used in the budget request to Congress.

In fact, the chemistry division funds only about one third of reviewed research proposals it receives. The confusion comes [redacted]

article not
covered

there were 597 such continuing grant amendments paid by the chemistry division.

In fiscal year 1989, the chemistry division made 275 research grants, including Presidential Young Investigator Awards, from 832 reviewed research proposals—a 33% success rate. These figures include both new and renewal applications for research project support, but exclude the shared instrumental program (49% success rate), instrumentation and laboratory improvement (18%), research experiences for undergraduates (15% for sites), and postdoctoral research fellowships in chemistry (13%).

K. N. Houk
K. G. Hancock
Chemistry Division
National Science Foundation

Chemical education

SIR: Concern for the general state of chemical education, as in the ACS president's speech (C&EN, Jan. 1, page 2) and the Congressional Outlook article (C&EN, Jan. 8, page 8), often suggests remedial action that is marginal or indirect—as when the focus is on organization and funding. Easily overlooked in major pronouncements are insights such as those of Roald Hoffmann in his talk at PACIFICHEM '89 (C&EN, Jan. 1, page 6). Some of us who have become directly involved with introductory chemistry agree with his comments that most introductory chemistry instruction alienates students from science and develops an attitude that is not the basis for democracy. The list of those who suffer begins with the individual student and runs through and beyond the chemical profession.

From their introductory chemistry experiences, most students learn that the world is not understandable; that is, they learn that they themselves cannot understand it. They find that they are not even encouraged or expected to understand it! They should learn what others—teachers, textbook writers, or scientists—say. Students tell me, sometimes belligerently, "How should I know, that's just what my teacher told me." Although there is no direct path from this attitude to a general acceptance of offi- [redacted] pronouncements, we have missed [redacted] chance to foster dependence on the

Correction

- [redacted] March 26, page 13: Iraq, not Iran, [redacted] s one of the three nations known to [redacted] possess chemical weapons.

Top 50 Chemicals Production Slowed Markedly Last Year

Output increased only 0.2% to 611 billion lb; inorganics production moved up a modest 2%, while organics faltered, slipping 3.3% from 1988

Marc S. Reisch,
C&EN Northeast News Bureau

Although chemical exports and domestic demand started strong in 1989, an economic slowdown in the second half of the year put the brakes on industry production. According to C&EN's annual ranking of the 50 largest volume chemical products, total production in that group in 1989 increased only 0.2% from 1988. Production just eked past the 1988 all-time high to a new record high of 611 billion lb.

As 1988 ended with record demand for most chemical products, new capital projects began to come on stream during 1989. But demand did not materialize to absorb all of the industry's output. According to seasonally adjusted Federal Reserve Board data, chemicals and allied products output rose 1.8% between the first and fourth quarter of 1989, while industry capacity rose 3.9%. Concurrently, industry capacity use fell from 88.9% in first-quarter 1989 to 87% in the fourth quarter.

As more product became available during the second half of 1989, prices finally eased. Labor Department statistics show that prices for chemicals and allied products peaked in April and May of 1989 at an index of 124.9 (1982 = 100). By December the chemicals and allied products index had dropped to 118.6, down 2.5% from a year earlier. Still, December 1989 prices were 7.2% above those in January 1988. The industrial chemicals subcategory illustrates the same trend. The producer price index for that category peaked in May 1989 at 117.8 and declined 3% by December, having dropped as low as 4.9% off the May peak in November. However, the December 1989 index for the

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1989. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, the production figures for earlier years that appear in the table on page 12 are different in some cases from those published in last year's Top 50 article. The final reports also can affect the rankings of chemicals. For the table published on page 12, the 1988 ranking of 22 chemicals is different from last year's listing (C&EN, April 10, 1989, page 12). Production revisions affected the 1987 ranking of only one chemical in the table appearing last year.

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster also includes basic inorganic chemicals but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead burned) dolomite is excluded in lime production.

In the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included.

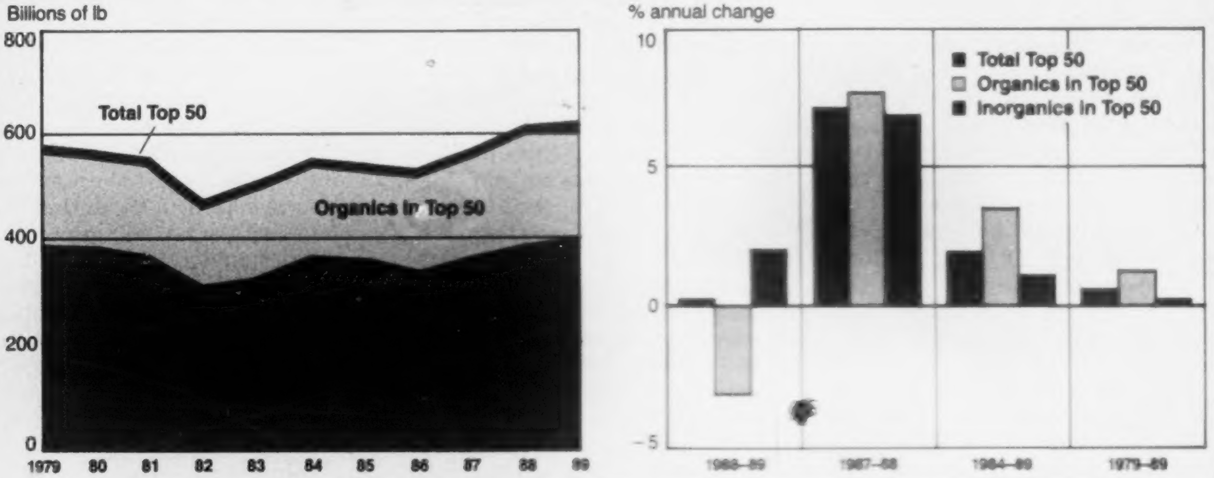
Production figures are published by the government in a variety of units—pounds, tons, cubic feet, gallons, metric tons, and, most recently, kilograms and liters. Where the latter two units are used, they have been converted into the common units that the government and industry have historically used as points of reference. To provide an accurate ranking and to make comparison of production volumes easier, C&EN lists production not only in common units, but converted to pounds.

Top 50 chemicals production totaled about 611 billion lb in 1989

Rank			Billions of lb		Common units[b]		Average annual growth			
1989	1988[a]		1989	1988	1989	1988	1988–89	1987–88	1984–89	1979–89
1	1	**Sulfuric acid**	86.80	84.28	43,399 tt	42,141 tt	3.0%	7.3%	0.8%	0%
2	2	**Nitrogen**	53.77	52.32	742 bcf	722 bcf	2.8	10.4	2.3	5.7
3	3	**Oxygen**	37.75	37.42	456 bcf	452 bcf	0.9	15.9	3.4	0
4	4	**Ethylene**	34.95	37.20	34,953 mp	37,203 mp	–6.0	6.3	2.2	1.6
5	5	**Ammonia**	33.76	33.64	16,878 tt	16,821 tt	0.3	4.1	0.2	–1.0
6	6	**Lime**[c]	32.99	32.02	16,495 tt	16,011 tt	3.0	5.5	0.6	–2.4
7	7	**Phosphoric acid**	23.12	23.35	11,559 tt	11,677 tt	–1.0	11.5	0.3	1.1
8	8	**Chlorine**	22.32	22.51	11,161 tt	11,257 tt	–0.9	2.5	0.8	–0.9
9	10	**Sodium hydroxide**	22.15	21.05	11,075 tt	10,527 tt	5.2	–8.6	0.3	–1.4
10	9	**Propylene**	20.23	21.22	20,229 mp	21,224 mp	–4.7	14.6	5.4	3.6
11	11	**Sodium carbonate**[d]	19.79	19.26	9,896 tt	9,632 tt	2.7	8.3	3.1	1.8
12	12	**Nitric acid**	15.98	15.98	7,991 tt	7,991 tt	0	12.5	0.7	–1.1
13	13	**Urea**[e]	15.47	15.83	7,733 tt	7,914 tt	–2.3	6.4	0.8	1.0
14	14	**Ammonium nitrate**[f]	15.11	15.01	7,557 tt	7,504 tt	0.7	17.0	1.1	–0.9
15	15	**Ethylene dichloride**	13.68	13.03	13,675 mp	13,028 mp	5.0	–5.6	5.0	1.5
16	16	**Benzene**	11.67	11.73	1,585 mg	1,593 mg	–0.5	0.5	3.8	–0.5
17	18	**Carbon dioxide**[g]	10.83	10.12	5,413 tt	5,058 tt	7.0	2.6	3.5	6.1
18	20	**Vinyl chloride**	9.62	9.06	9,618 mp	9,058 mp	6.2	10.1	9.6	4.2
19	19	**Ethylbenzene**	9.22	9.93	9,223 mp	9,929 mp	–7.1	5.5	4.1	0.9
20	17	**Terephthalic acid**[h]	8.31	10.23	8,309 mp	10,234 mp	–18.8	26.2	7.0	3.0
21	21	**Styrene**	8.13	8.98	8,129 mp	8,984 mp	–9.5	11.1	1.1	0.8
22	22	**Methanol**	7.14	8.14	7,139 mp	8,142 mp	–12.3	11.7	–2.7	–0.3
23	24	**Formaldehyde**[i]	6.37	6.28	6,370 mp	6,280 mp	1.4	3.3	1.8	0.6
24	23	**Toluene**[j]	5.84	6.35	805 mg	875 mg	–8.0	–5.7	2.0	–2.2
25	29	**Xylene**	5.80	5.48	805 mg	761 mg	5.8	–4.3	–1.2	–1.9
26	28	**Ethylene glycol**	5.50	5.52	5,499 mp	5,517 mp	–0.3	22.2	2.7	1.5
27	27	***p*-Xylene**	5.49	5.60	5,494 mp	5,601 mp	–1.9	8.7	5.2	1.7
28	25	**Ethylene oxide**	5.32	5.95	5,322 mp	5,953 mp	–10.6	5.9	–1.4	–0.8
29	30	**Hydrochloric acid**	5.26	5.28	2,628 tt	2,640 tt	–0.5	–11.9	–0.5	–1.6
30	26	**Methyl *tert*-butyl ether**[k]	4.98	5.68	4,976 mp	5,680 mp	–12.4	68.4	29.3	na
31	31	**Ammonium sulfate**	4.71	4.67	2,354 tt	2,333 tt	0.9	6.9	2.6	0
32	32	**Cumene**	4.54	4.46	4,535 mp	4,455 mp	1.8	7.3	3.9	1.5
33	33	**Phenol**[l]	3.89	3.56	3,893 mp	3,562 mp	9.3	9.9	6.1	2.7
34	36	**Acetic acid**	3.83	3.16	3,826 mp	3,159 mp	21.1	–2.1	7.9	1.6
35	34	**Potash**[m]	3.35	3.35	1,521 tmt	1,521 tmt	0	20.5	–0.6	–3.7
36	37	**Propylene oxide**	3.20	3.11	3,200 mp	3,110 mp	2.9	19.2	12.5	3.6
37	35	**Butadiene**[n]	3.09	3.17	3,094 mp	3,169 mp	–2.4	5.6	4.8	–1.5
38	38	**Carbon black**	2.91	2.92	2,913 mp	2,916 mp	–0.1	7.0	0.1	–1.3
39	39	**Acrylonitrile**	2.61	2.61	2,608 mp	2,609 mp	0	2.3	3.3	2.6
40	42	**Acetone**	2.50	2.30	2,497 mp	2,303 mp	8.4	10.6	6.0	–0.6
41	40	**Vinyl acetate**	2.47	2.56	2,470 mp	2,561 mp	–3.6	2.2	4.1	2.2
42	42	**Cyclohexane**	2.39	2.30	2,389 mp	2,297 mp	4.0	2.1	3.7	–0.1
43	41	**Aluminum sulfate**	2.35	2.46	1,173 tt	1,232 tt	–4.8	0.7	0.8	–1.1
44	44	**Titanium dioxide**	2.22	2.04	1,110 tt	1,022 tt	8.6	7.4	5.9	4.1
45	48	**Calcium chloride**[o]	1.92	1.46	960 tt	729 tt	31.7	–5.7	–1.8	–0.2
46	46	**Sodium silicate**	1.75	1.62	877 tt	812 tt	8.0	–14.7	5.1	0.8
47	47	**Adipic acid**	1.64	1.60	1,640 mp	1,600 mp	2.5	1.8	3.4	–0.6
48	45	**Sodium sulfate**[p]	1.60	1.63	800 tt	817 tt	–2.1	1.5	–1.7	–3.3
49	49	**Isopropyl alcohol**	1.43	1.39	1,432 mp	1,389 mp	3.1	5.8	0.5	–2.8
50	50	**Caprolactam**	1.31	1.26	1,312 mp	1,261 mp	4.0	8.6	5.0	3.3
		TOTAL ORGANICS	**210.61**	**217.69**			**–3.3%**	**7.8%**	**3.6%**	**1.4%**
		TOTAL INORGANICS	**400.44**	**392.41**			**2.0%**	**7.0%**	**1.3%**	**0.2%**
		GRAND TOTAL	**611.04**	**610.11**			**0.2%**	**7.3%**	**2.0%**	**0.6%**

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. c Except refractory dolomite. d Natural and synthetic. e 100% basis. f Original solution. g Liquid and solid only. h Includes both acid and ester without double counting. i 37% by weight. j All grades. k Production data for earlier years unavailable. l Synthetic only. m K_2O basis. n Rubber grade. o Solid and liquid. p High and low purity. na = not available.

Production of Top 50 chemicals up marginally



industrial chemicals subcategory was 15% above the producer price index in January 1988.

To be sure, the price of available chemical product was not entirely the creature of supply and demand. Labor costs and energy prices in late 1989 were higher than in 1988. For instance, Department of Labor statistics show that chemical industry production worker earnings increased 4.1% between December 1988 and December 1989, and the producer price for crude oil gained 35% during the same period of time, according to the Commerce Department. It is easy, then, to understand why the industry finds itself in an earnings slowdown (C&EN, Feb. 19, page 10), as the moderation in demand for its largest volume products in 1989 was accompanied by a decline in prices even as labor and energy costs increased.

Slow demand from traditional large chemical industry customers also has hurt the chemical industry. Domestic motor vehicle output declined 22.5% in the fourth quarter of 1989 from the third quarter, following a moderate decline in the third quarter, notes the Commerce Department. New housing starts continued slow last year. Fertilizer demand remained fairly strong. Exports held up better than expected in 1989, but did not take up the slack from slowdowns in domestic demand.

Among the largest volume chemicals produced in the U.S., sulfuric acid remained on top with total production of 86.8 billion lb, a 3.0% increase from 1988. Nitrogen continued to rank a distant second, with production at 53.8 billion lb, up 2.8% from 1988. In both cases, the rate of increase in production slowed considerably from the previous year when the rise in sulfuric acid production was 7.3% and that in nitrogen production was 10%.

Organic chemicals, making up some 34% of the Top 50, did not make nearly as good a showing in 1989 as they did in 1988. Their production actually decreased 3.3% from 1988 when the organic chemicals category made up some 36% of the Top 50 and had grown 7.8% from the previous year. Over the five-year period 1984–89, production of organic chemicals among the Top 50 increased an average of 3.6% a year. Historically their output has grown at a much slower pace. Between 1979 and 1989, ouput of organic chemicals among the Top 50 grew at a compound annual rate of only 1.4% a year.

By contrast, the inorganic segment of the Top 50 increased its production in 1989. Output for that category rose 2.0% from 1988, when production grew at a faster clip, 7.0%, compared with the year earlier. Over the five-year period 1984–89, production of organic chemicals among the Top 50 increased at an average 1.3% a year. Historically, output for the group has grown at an even slower pace than that of the organics in the Top 50. Between 1979 and 1989, output of inorganic chemicals among the Top 50 grew at an annual rate of only 0.2%.

Of the Top 50 chemicals, production of 26 of them increased in 1989. By contrast, production of 42 increased in 1988. Total production of the Top 50 chemicals, at 611 billion lb, was up a mere 0.2% from 1988 compared with the 7.3% growth for the whole group from 1987 to 1988. However, the 1989 level of production just managed to edge past the historic high set last year at 610 billion lb. Still, the 1989 production level was 32% higher than the decade-low level of 464 billion lb registered in 1982.

For the Top 50 group, composite output increased at a compound annual rate of 2.0% between 1984 and 1989. Long-term growth for the group as a whole was an even slower pace: Between 1979 and 1989, Top 50 production grew at an average annual rate of 0.6%.

Leading the inorganics' production gains was calcium chloride, up 32% from 1988 to 1.9 billion lb. The gain pushed calcium chloride from 48th place in 1988 to 45th place in the 1989 rankings. The calcium chloride data from 1987 and 1988 may not be entirely accurate; a statistician for the Bureau of Mines notes some problems in collecting and compiling figures for earlier years. According to data available, calcium chloride production has declined at a compound annual rate of 0.2% between 1979 and 1989.

The next largest gain among inorganics was by titanium dioxide, up 8.6% to 2.2 billion lb. The gain placed it in 44th place, the same ranking it occupied in 1988 when output increased 7.4%. Sodium silicate production recovered in 1989 following a drop the previous year; output increased 8.0% to 1.8 billion lb following a 15% drop in 1988. The gain placed the chemical in 46th place, the same ranking it occupied in 1988.

Although the inorganics showed the best performance as a group in 1989, some were significant underachievers. Aluminum sulfate production declined 4.8% in 1989 to 2.4 billion lb, compared with a 0.7% increase in 1988. And sodium sulfate production declined 2.1% to 1.6 billion lb in contrast with a 1.5% increase in the previous year.

For organic chemicals, 1989 production growth was led by acetic acid, up 21% to 3.8 billion lb. As a result, acetic acid moved from 36th place to 34th place in the 1989 list. Phenol also showed good growth, up 9.3% to 3.9 billion lb, but remained in 33rd place. The next largest gainer in the organics category was acetone, up 8.4% to 2.5 billion lb in 1989 and into 40th place.

Components of the organic chemicals group among the Top 50 showed the largest year-to-year declines in 1989 of all 50 chemicals. The most dramatic was a 19% drop for terephthalic acid to 8.3 billion lb. In 1988, production of the chemical increased 26% to 10.2 billion lb.

Looking at growth over the past 10 years, 24 of the Top 50 chemicals have recorded overall production increases. The best long-term performer has been carbon dioxide, output of which grew at an annual compound rate of 6.1% during the period. Nitrogen has also grown at a good rate, 5.7%. Other chemicals with sizable annual growth rates were vinyl chloride, 4.2%; titanium dioxide, 4.1%; propylene oxide, 3.6%; and propylene, 3.6%. Potash registered the largest average annual rate of decline over the past 10 years, with output falling at a compound annual rate of 3.7%. □

Polymer output dips for first time in seven years

Overall U.S. production of commercial polymers, including plastics, synthetic fibers, and synthetic rubber, declined 2.0% in 1989 from a year earlier. The decline was the first in seven years and put total 1989 polymer output at 59.3 billion lb following the 60.5 billion lb record output of 1988.

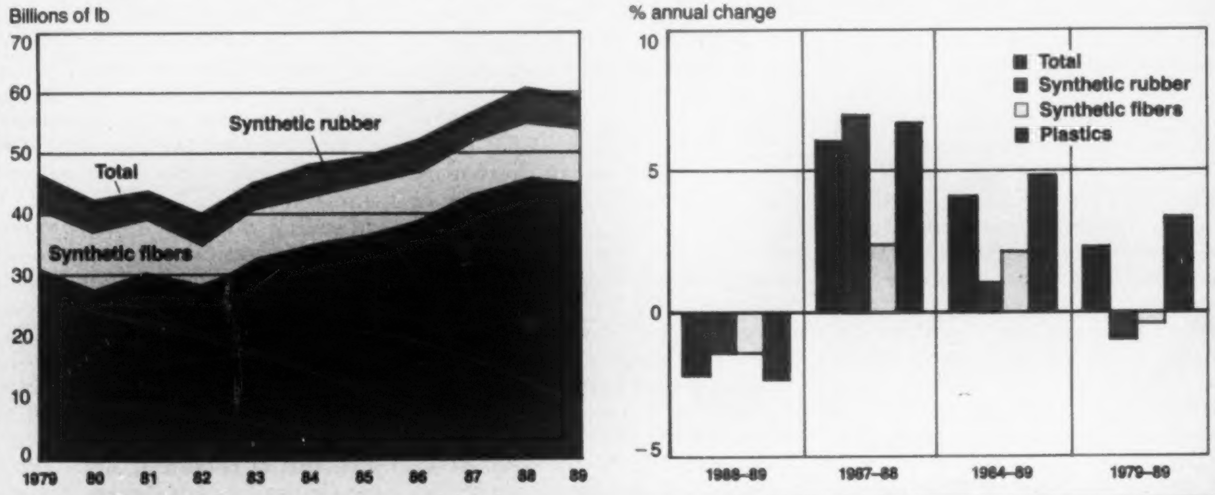
Plastics output, which accounted for more than three quarters of the polymer group production total, declined 2.2% in 1989. In 1988, plastics production grew 6.8% from 1987.

The decline in U.S. plastics production might have been greater if the volume of exports had not grown so dramatically as it did in a number of categories. Export growth was particularly strong for unsaturated polyester resins (up 53% to 24.2 million lb), high-density polyethylene (up 42% to 921 million lb), polystyrene (up 39% to 224 million lb), and polyvinyl chloride and copolymers (up 77% to 913 million lb).

Within the plastics category, thermoplastics production dropped 2.1% but showed less of an overall decline than thermosetting resins, production of which declined 3.0%. Among the thermoplastics, polyvinyl chloride and copolymers registered modest growth of 1.7%, and polypropylene production edged up 1.1%. All the other resins within the grouping showed a decline. The most dramatic decline in production was for low-density polyethylene, down 6.4%, followed by high-density polyethylene, down 3.6%, and then polystyrene, down 1.6%.

Among the thermosetting resins, melamine put in a surprisingly strong showing, up almost 11%.

Output of plastics, synthetic fibers, and synthetic rubber declined in 1989



Total polymer output exceeded 59 billion lb last year

	Billions of lb		Common units					Average annual growth			
	1989	1988	1989	1988	1987	1984	1979	1988-89	1987-88	1984-89	1979-89
PLASTICS (millions of lb)											
Thermosetting resins	**6.39**	**6.59**	**6,388**	**6,588**	**6,265**	**5,549**	**4,856**	**−3.0%**	**5.2%**	**2.9%**	**2.8%**
Phenol and other tar acid resins	2.86	**3.07**	2,862	3,066	2,870	2,502	1,781	−6.7	6.8	2.7	4.9
Urea resins	1.47	**1.43**	1,469	1,425	1,382	1,199	1,367	3.1	3.1	4.1	0.7
Polyesters (unsaturated)	1.32	**1.40**	1,319	1,404	1,368	1,232	1,147	−6.1	2.6	1.4	1.4
Epoxies (unmodified)	0.51	**0.49**	509	486	433	406	361	4.7	12.2	4.6	3.5
Melamine resins	0.23	**0.21**	229	207	212	210	200	10.6	−2.4	1.7	1.4
Thermoplastic resins	**38.77**	**39.61**	**38,772**	**39,608**	**36,992**	**30,036**	**26,768**	**−2.1%**	**7.1%**	**5.2%**	**3.8%**
Low-density polyethylene	9.73	**10.40**	9,728	10,397	9,599	8,413	7,793	−6.4	8.3	2.9	2.2
PVC and copolymers	8.49	**8.35**	8,488	8,350	7,971	6,760	6,119	1.7	4.8	4.7	3.3
High-density polyethylene	8.10	**8.40**	8,100	8,400	7,995	6,085	5,010	−3.6	5.1	5.9	4.9
Polystyrene[a]	5.10	**5.19**	5,103	5,187	4,780	3,838	4,005	−1.6	8.5	5.9	2.5
Polypropylene	7.35	**7.27**	7,353	7,274	6,647	4,940	3,841	1.1	9.4	8.3	6.7
TOTAL[b]	**45.16**	**46.20**	**45,160**	**46,196**	**43,257**	**35,585**	**31,624**	**−2.2%**	**6.8%**	**4.9%**	**3.6%**
SYNTHETIC FIBERS (millions of lb)											
Cellulosics	**0.50**	**0.61**	**500**	**614**	**605**	**589**	**930**	**−18.6%**	**1.5%**	**−3.2%**	**−6.0%**
Rayon[c]	0.28	**0.40**	282	400	414	390	606	−29.5	−3.4	−6.3	−7.4
Acetate[d]	0.22	**0.21**	218	214	191	199	324	1.9	12.0	1.8	−3.9
Noncellulosics[b]	**8.52**	**8.53**	**8,515**	**8,526**	**8,316**	**7,473**	**8,419**	**−0.1%**	**2.5%**	**2.6%**	**0.1%**
Polyester	3.59	**3.68**	3,593	3,680	3,541	3,392	4,178	−2.4	3.9	1.2	−1.5
Nylon[e]	2.74	**2.67**	2,740	2,670	2,689	2,412	2,721	2.6	−0.7	2.6	0.1
Olefin[f]	1.64	**1.59**	1,640	1,588	1,494	998	759	3.3	6.3	10.4	8.0
Acrylic[g]	0.54	**0.59**	542	588	592	671	761	−7.8	−0.7	−4.2	−3.3
TOTAL[b]	**9.02**	**9.14**	**9,015**	**9,140**	**8,921**	**8,062**	**9,349**	**−1.4%**	**2.5%**	**2.3%**	**−0.4%**
SYNTHETIC RUBBER (thousands of metric tons)											
Styrene-butadiene[h]	1.93	**2.00**	874	909	850	958	1,378	−3.9	6.9	−1.8	−4.5
Polybutadiene	0.91	**0.90**	411	407	371	359	397	1.0	9.7	2.7	0.3
Ethylene-propylene	0.57	**0.58**	260	263	254	215	175	−1.1	3.5	3.9	4.0
Nitrile	0.15	**0.17**	69	76	69	67	75	−9.2	10.1	0.6	−0.8
Other[i]	1.52	**1.50**	688	679	638	556	502	1.3	6.4	4.4	3.2
TOTAL[b]	**5.08**	**5.15**	**2,302**	**2,334**	**2,182**	**2,155**	**2,527**	**−1.4%**	**7.0%**	**1.3%**	**−0.9%**

a No longer includes acrylonitrile-butadiene-styrene, or styrene-acrylonitrile resins; historical data are restated. b Totals are for those products listed and may not add because of rounding. c Based on C&EN estimates. d Includes diacetate and triacetate yarn, but does not include cigarette tow. Beginning with 1985, includes rayon yarn. e Excludes aramid after 1982. f Includes olefin film, olefin fiber, spun-bonded polypropylene, and vinyon. g Includes modacrylic. h Excludes high-styrene latex. i Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. **Sources:** Society of the Plastics Industry, Textile Economics Bureau, Rubber Manufacturers Association

Melamine resins were the only component to record an actual production decline in 1988 compared with 1987. Other thermosetting resins showed more modest annual growth in 1989: Unmodified epoxies production rose 4.7%, and urea resins output gained 3.1%. However, production of the largest component of the thermosetting resins category, phenol and other tar acid resins, declined 6.7%.

For the five-year period 1984–89, the plastics segment still grew at a compound annual rate of 4.9%. For the 10-year period 1979–89, plastics output grew at an annual compound rate of 3.6%.

Output of synthetic rubber, another polymer segment, declined 1.4% last year compared with a 7.0% increase the previous year. Production of 5.1 billion lb was close to last year's 5.2 billion lb, though still not so good as the high for the decade set in 1979 at 5.6 billion lb.

Two out of five segments of the synthetic rubber category registered overall increases in 1989. One of these, listed as other and including neoprene, butyl, polyisoprene, and other rubbers, had a production increase of 1.3%. The other segment showing an increase was polybutadiene, production of which rose a modest 1.0%. Of the declines, nitrile rubber production showed the greatest, down 9.2%, followed by styrene-butadiene rubber, down 3.9%, and ethylene-propylene, down only 1.1%.

For another polymers group, synthetic fibers, output declined modestly in 1989 following the slow growth of the previous year. Production of synthetic fibers slipped 1.4% in 1989 after a 2.5% increase the previous year. Imports of finished textiles resumed their upward growth in 1989, putting even greater pressure on domestic fiber producers who supply domestic textile manufacturers. In addition, Avtex Fibers, once the largest U.S. rayon manufacturer, shut down its Front Royal, Va., plant because of mounting environmental and cash flow problems (C&EN, March 19, page 11).

Over the past five years, the synthetic fiber category has grown at a compound annual rate of 2.3%. For the past 10 years, production has declined at an average annual rate of 0.4%.

Marc Reisch

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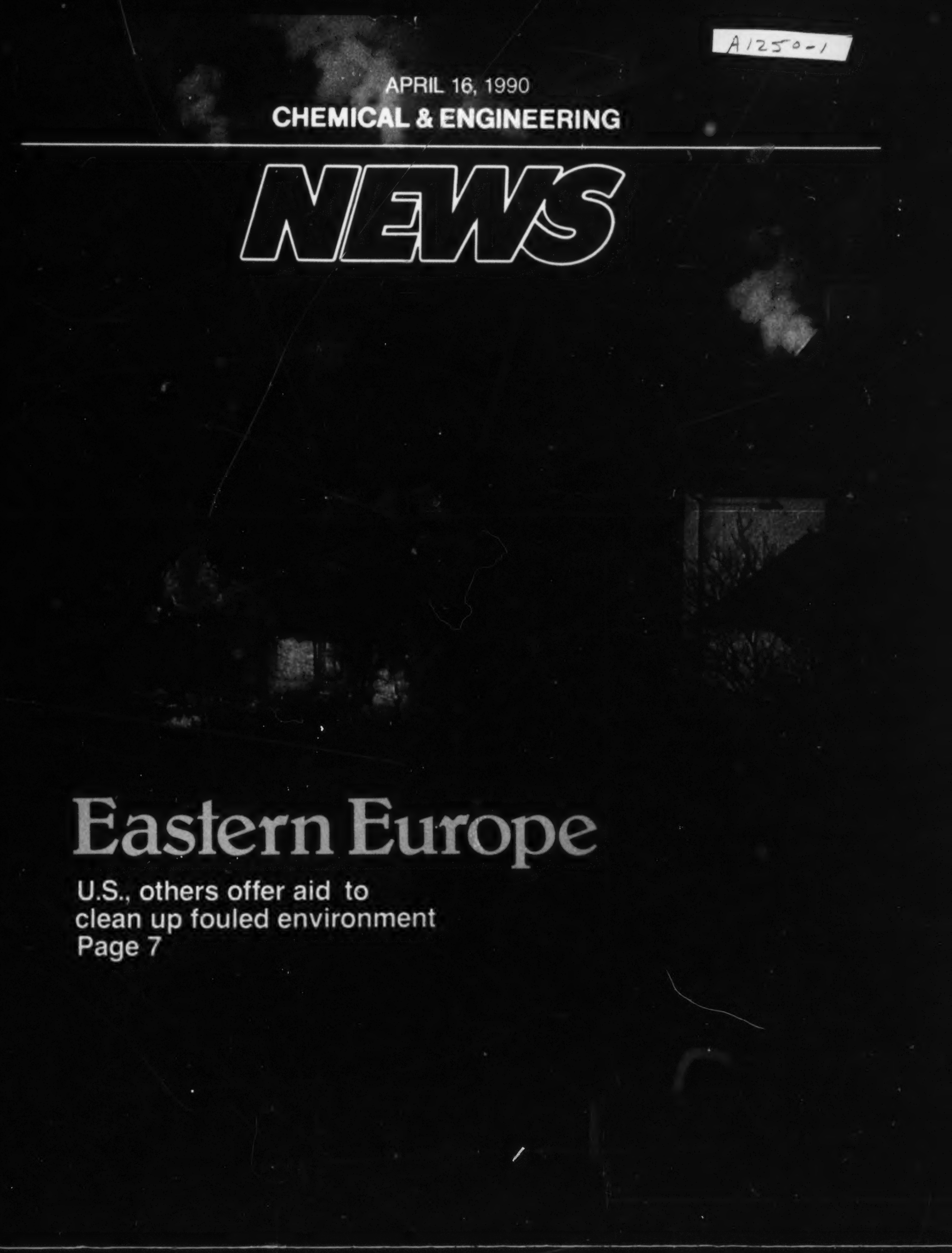
NEWS



Eastern Europe

U.S., others offer aid to
clean up fouled environment
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News of the Week

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- **Soviets plan "technopolis" network—communities oriented toward commercializing high-technology research.** Page 5
- **World chemical demand is expected to grow 56% by the year 2000 according to study by U.K. chemical industries group.** Page 6
- **On basis of its study, National Toxicology Program may classify sodium fluoride as showing equivocal evidence for carcinogenic activity.** Page 6

Cover: View of Copsa Mica, Romania. Photo by Anthony Suau/Black Star

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Steady string of mergers has meant fast growth for Rhône-Poulenc Inc., U.S. arm of the giant French chemical company. Page 19

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LETTERS

CHEMICAL SAFETY

Titanium metal explosion

SIR: In the course of a silver recovery operation, a dark-colored sludge—later found to consist primarily of titanium metal flake—was settled, separated, and drained from a spent nitric acid stripping solution containing about 12% by weight of silver nitrate. Before drying was complete, a violent explosion occurred. A plant workman, the only person within visual range, was killed instantly. Although there was no apparent reason for him to have disturbed the tray at the time, the exact circumstances of initiation are not known. In addition to other damage, fragments propelled by the blast penetrated two nearby steel drums; the largest hole was about 6 inches in diameter. Partially dried sludge was widely distributed over a driveway, building walls, and rooftops. This material became sensitive as it dried and was repeatedly set off by the shoes and tools of cleanup workers.

Subsequent analysis and laboratory study demonstrated that the settled and drained titanium flake retained about 14 times its own weight of the silver nitrate solution, leading to a dried sludge containing about 60% by weight of silver nitrate and 40% by weight of titanium metal. Such compositions were found to explode vigorously upon heating or when subjected to friction or impact. The explosion reaction can be depicted as follows:

$$3Ti + 2AgNO_3 \rightarrow 3TiO_2 + 2Ag + N_2$$

For the balanced composition depicted above the standard heat of reaction, frequently a good approximation of the heat of explosion, is about 5 kilojoules per g, comparable to the heat of explosion of conventional high explosives.

This accident demonstrates that finely divided titanium metal can form extremely hazardous compositions when dispersed in a strong oxidant such as silver nitrate.

E. S. Shanley
Arthur D. Little Inc.

Use of asbestos

SIR: The journal *Science* published a study of medical experts who found that the "asbestos panic" may be leading to costly and unnecessary removal efforts. We were brainwashed into believing that asbestos is a very dangerous carcinogen. Nobody can dispute the fact that asbestos is an odorless, nontoxic mineral that does not give up any vapors. It is also the best filtering material.

Those who condemn the use of asbestos do not recognize that the number of fire deaths has sharply increased since insulation containing those fibers has been removed from many buildings and is not installed any more. They also seem not to know that many of the materials that replaced asbestos are far more dangerous to our health than it was. The carbon monoxide, nicotine, nail polish, fumes emanating from some kinds of carpeting and insulation materials, etc. that are circulated with the cooled or heated air of totally climate-controlled buildings are thousands of times more harmful to our lungs than floating asbestos fibers. Asbestos is retained by the air filters.

The employees in the Environmental Protection Agency headquarters outside Washington, D.C., get sick from inhaling the chemicals emanating from the so-said safe wall and floor coverings. They have to go outside for extended periods to recover. Others had to take leaves of absence or could not return to work there.

If we are forced to spend more than $30 billion to remove asbestos from public and private buildings, we should assume that asbestos is a major cause of death in the U.S. A 1986 statistic of causes of death does not even list the 12,000 people who, according to EPA claims, die annually from asbestos-related causes.

All persons who work in areas filled with enormous amounts of dust are at risk to be afflicted with lung diseases. Coal miners, flour millers, bakers, etc. fall into this category. If ever a school teacher or student would have come

Continued on page 41

Corrections

- April 2, page 10: The eighth company listed in the table should read Celgene, not Calgene. Footnote c in the table should read: Consolidated figures for the year to reflect merger with Plant Genetics in July 1989.
- April 2, page 25: Ted Halchak joins Celgene Corp., not Calgene, as manager of commercial development.

its development. Earlier this year, Jean-René Fourtou, chairman of the parent company, indicated that the Rorer Group acquisition will be the last major buy for Rhône-Poulenc for some time. This means that Rhône-Poulenc Inc., while there may be further smaller acquisitions, will be switching from the acquisitions strategy that it had to have in the 1980s to grow as fast as it did, to an internal growth strategy.

Neff agrees that the company is embarking on a new phase. And it is evidenced in a number of ways, mainly in the methods of achieving internal growth. He indicates that strategic premiums can be garnered from the acquisitions by the synergies that may be inherent between them, by increasing revenues, and by lowering costs. For agricultural chemicals, although there was some cost cutting, the major emphasis has been on increasing sales through expanded markets and new formulations. For basic chemicals, the main focus has been on cost cutting.

With many of the new specialty-oriented acquisitions, there will be efforts to decrease costs, but the main thrust will be on building sales. "I don't think that these businesses were managed on a worldwide basis," Neff says.

The firm will get a chance to see what it can do worldwide. In the future, four of its businesses will be managed from the U.S. These are surfactants, food ingredients, recycle and recovery of chemical wastes, and seeds. Previously, these units were run from France.

Just as the management of some worldwide businesses is being switched to the U.S., so is technical support and R&D for some business units. It is almost axiomatic that when foreign-owned companies reach some critical mass, it is difficult for the parent to do all the R&D and impose it on the subsidiary. Rhône-Poulenc Inc. seems to be approaching that stage. In basic chemicals, the technology is still largely brought in from France. It is this technology that the firm is using in its wet-process phosphoric acid plant being built at Geismar, La.

But in other areas, such as insecticides, long a strong suit of the agrochemicals unit, R&D is done at its Research Triangle Park, N.C., facility. And technical work will be done in the U.S. for the four worldwide business units managed here. Also, Neff says, technical support for textiles and epoxies is done in the U.S. It is natural, he says, that Rhône-Poulenc will attempt to tap U.S. R&D in that the U.S. chemical industry leads in biotechnology, advanced materials, and some other chemically related areas.

Neff ticks off a number of goals that he has for the company:

- To be a diversified chemical company that is one of the top three participants in such businesses as agrochemicals, sulfur products, recycle and recovery of chemical wastes, food ingredients, and surfactants.
- To keep technology as a significant part of the product offering.
- To develop low-cost positions, where appropriate.
- To continue to represent at least 20% of Rhône-Poulenc Group's sales.

But with the change from an acquisitions strategy to one of internal growth, Neff has a further goal that is ambitious. He wants sales to double over the next 10 years. ☐

Expansions delayed to ease ethylene overcapacity

The vast array of new ethylene capacity previously announced for startup between 1990 and 1992 is being reduced drastically, and companies are now extending the timing for expected startups to much further into the 1990s for many of the projects. The capacity additions were spawned by the surging demand for ethylene during 1988 and early 1989 and by soaring selling prices of the same period.

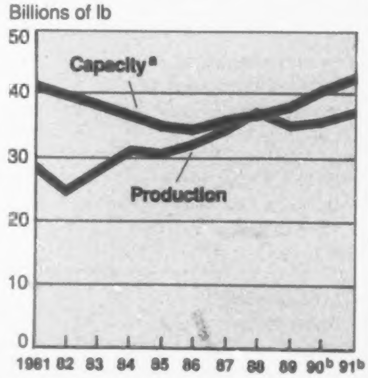
Those additions would have brought capacity to 50 billion lb per year by 1993. Demand for ethylene now looks as if it might reach 40 billion lb by 1993 if the U.S. economy stays at its current sluggish growth pace and if exports of derivatives decline no more than modestly. Obviously, overcapacity and pressure on prices could have become serious.

As a group, U.S. ethylene producers are exercising caution, according to Earl H. Armstrong, vice president of DeWitt & Co., speaking at the firm's annual Petrochemical Review in late March. The rush to expand capacity has slowed, easing concerns that another dismal era of low operating rates and marginal profitability, like that of the mid-1980s, would recur. Nevertheless, on-going capacity additions are slowing operating rates and putting pressure on prices, according to a number of industry sources at the National Petroleum Refiners Association's 15th Annual International Petrochemical Conference held in San Antonio early this month.

Nonetheless, several major capacity additions will be completed and started up by early 1991, along with some small expansions through process improvements. Quantum Chemical, scheduled to start up a 1.5 billion lb-per-year unit in the fourth quarter of this year, will have the first of the new large ethylene plants to be completed. That plant and another being built by Phillips 66 for startup in early 1991 will add 3 billion lb of capacity, nearly 8% of the present total.

Expansion projects completed in 1989, as well as other small additions recently completed or to be finished later this year, will add more than 2 billion lb to nameplate capacity or about half of the expan-

Ethylene capacity additions have eased supply crunch



a Estimated yearly average of operable nameplate capacity. b Forecast. **Sources:** U.S. International Trade Commission, National Petroleum Refiners Association, C&EN estimates sion in demand this year. In-place and operable nameplate capacity in early March exceeded 40 billion lb, says John R. Hodson, who heads Hodson & Associates of Houston. He forecasts additions to capacity of more than 10 billion lb as either expansions or new additions.

This year, the additional capacity exceeding demand growth will lower the average operating rate to less than 90% of nameplate capacity. The ethylene industry's operating rate has not been below 90% of nameplate capacity since 1985.

Demand for ethylene in the U.S. this year is forecast to grow 3 to 4%, with similar growth expected in 1991. With that rate of increase next year, demand will reach 37.8 billion lb, exceeding the previous record of 37.4 billion lb in 1988.

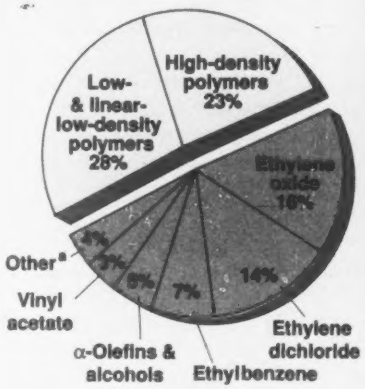
Last year, consumption of ethylene fell 2 billion lb, as production of many kinds of plastic resins declined. Demand for plastics decreased less than production because inventories were reduced as selling prices decreased. The slowing in demand and the potential of a large increase in capacity also pushed down ethylene prices more than a third from the peak price of about 34 cents per lb. Ethylene inventories, as well, were reduced.

Both list and spot prices for ethylene firmed quickly following the unusually cold weather along the Gulf Coast in late December, during which many ethylene and derivatives units were damaged by equipment freeze-up. Consumers were caught with minimal inventories of derivatives. When the plants were repaired, they were operated at high rates to meet a surge in demand. Weather caused a loss of 1.1 billion lb of ethylene through February, estimates John S. Doerr, who heads International PC, a Houston consulting firm.

The lost ethylene and derivatives output was made up almost completely by the end of the first quarter this year. Spot prices for ethylene began to drop below the list price of 24 cents a lb in late March. Some further weakening may occur this quarter, but the declines will be much smaller than those occurring monthly during the second half of 1989.

Because of lowered inventories of ethylene derivatives, particularly the polyethylenes, second-quarter demand is expected to approximate the first quarter, giving good demand for ethylene during the first half of 1990, says Doerr. The second half of 1990 is more uncertain. With nominal inventories in place, some producers say, U.S. production could increase because the economy is expected to grow modestly.

Polymers account for most U.S. ethylene use



1989 ethylene consumption = 35.4 billion lb

a Acetaldehyde, ethylene-propylene elastomers, ethanol, and the like, including inventory change, exports, and losses. **Source:** Petrocon Associates

Expansions could raise ethylene capacity by 15 billion lb

Billions of lb	Expansion	Planned startup date	Status
Amoco Chemicals	1.5	1993	Deferred
Chevron Chemical	0.2	1989	1990
Dow Chemical	1.5	1992	On schedule
Exxon Chemical	1.0	1990	On schedule
Formosa Chemical	1.5	1992	Uncertain
Lyondell Petrochemical	0.6	1989	Done
Mobil Chemical	1.0	Uncertain	Not developed
Oxy Chemical	1.0	1993 or later	Deferred
Phillips 66	1.5	1991	On schedule
Quantum Chemical	1.5	1990 late	On schedule
Shell Chemical	1.0	1990-91	On schedule
Texaco[a]	0.4	1989	Done
Union Carbide[a]	0.5	1989	Done
Union Texas	0.4	1990	Done
Vista Chemical	0.4	1990	On schedule
Westlake Polymers	1.0	1991	On schedule
TOTAL	**15.0**		

a Restarted existing plant. **Source:** DeWitt & Co.

But prices could become a problem. For example, startup of more capacity to make polyethylenes could cause weakening of prices for these plastics. That could lead polymer producers to ask ethylene producers for lower prices.

Exports of derivatives will be a critical factor affecting ethylene demand this year, Doerr says. The net of exports over imports of these derivatives will be down slightly from the peak of last year, but will be equal to or better than the net of 1988. Strength in exports of derivatives will depend on the value of the dollar relative to other currencies, and on demand growth in other producing countries that will consume some derivatives that otherwise might be exported.

Polymers of ethylene and of second- or third-line derivatives (frequently containing other compounds) account for nearly 90% of consumption. A big fraction of the polymers go into consumer goods, most of which are nondurables. Until recently, population growth was the bottom limit for growth in the demand for these polymers. Markets captured from paper, metal, glass, wood, and other materials provided the larger growth rates. Now, however, the high visibility of plastics in the solid waste stream is bringing a surge of recycling efforts. In the future, if recycling proves to be economical, then cuts in demand for new polymers could slow demand for ethylene. Recycling's impact on demand and selling prices of ethylene could spur efforts to export more derivatives and could put more pressure on prices.

Growth in ethylene use in derivatives will vary widely. However, the dominance of polyethylenes, at more than 50% of ethylene consumption, puts them in control of the outlook for ethylene. Unless exports continue to grow much faster than the current forecast of a return to modest rate increases, polyethylene demand growth will average about 3 to 4% annually over the next five years. As industry sources point out, this growth will consume much of the output from capacity additions to be distributed over the same period.

Ethylene dichloride, most of which becomes polyvinyl chloride, could grow in demand for ethylene at above 4% annually, faster than demand in polyethylene will grow. Continued low prices for chlorine will help the competitive position of PVC. Because of their uses in detergent materials, α-olefins also are forecast to have a higher growth rate than polyethylenes. α-Olefins are growing rather rapidly in use as a comonomer for polyethylenes, but this use has an insignificant effect on ethylene demand. Together, the two uses account for less than 20% of ethylene demand. Other uses of ethylene, such as ethylene oxide and ethylbenzene, are expected to grow more slowly than the average 3% annually.

Some ethylene derivative makers building new plants or expanding existing plants are expected to reduce purchases of ethylene after the current round of plant expansions is completed. As a result, merchant demand for ethylene will decline about 2 billion lb, or about 5%, industry forecasters say. Merchant producers will seek out new markets for this ethylene. Although the quantity is small, selling it could have a negative effect on margins if marketers choose to lower prices.

Bruce Greek

U.K. chemical industry to boost capital spending

Despite a slowdown in the general economy that began late last year, the U.K. chemical industry nonetheless expects to boost its capital spending 9% in real terms over 1989. That's the prediction of the latest annual investment intentions survey undertaken by the U.K. Chemical Industries Association (CIA).

Capital spending for the year will be about $3.94 billion, the association predicts, even after it has factored in an automatic 10% decrease, for the first year in the rolling three-year survey, to correct for overoptimism. The prediction follows shortly after another survey by CIA, earlier this year, that production in the U.K. chemical industry would grow only 1% this year over 1989, a slowdown from 1989's 4% increase over 1988. In Western Europe as a whole, this year's output is expected to increase 2% over last year, which in turn was up 3% over 1988.

During the next three years, the survey indicates, total fixed capital spending—that is, spending on plant, machinery, vehicles, and buildings—will be about $12.2 billion, about $1.6 billion more than reported last year. The amount predicted for capital spending in 1991, for example, shows another 12% increase, to $4.42 billion, dropping off in 1992 to about the same level as that of this year.

Nearly half of total capital spending will go to build new plants and to expand existing units—29% on new facilities and 17% to expansions of existing plants. Another 34% will be spent on replacement of or modification to existing facilities, and some 14% to R&D facilities. Although nearly one third of the spending is designated for new production capacity or expansions, the emphasis in this year's survey, the 25th annual one, shows a slight shift toward replacement.

Spending on petrochemicals is the most rapidly rising product area, followed by pharmaceuticals. Together, the two sectors account for 83% of the real increase in planned spending over the three-year period.

The survey also points out that spending on health, safety, and environmental protection measures is continuing to rise. In fact, CIA estimates that such measures now make up 16% of total capital spending.

Patricia Layman

Polypropylene demand signals good year

Montedison, the Italian chemical company that owns, among other interests, polypropylene producer Himont, says that polypropylene is off to "a strong start" in 1990, after a positive year in 1989.

Analysis by Montedison's economic research department indicates significant sales increases in all the industrialized nations for polypropylene. Demand last year in the European Community as a whole increased 9% over 1988, but in the U.S., domestic sales of the polymer were up only about 3% over 1988.

All the industrialized nations of the EC showed increases, with the highest coming from France, up 9% over 1988; Italy, up 12%; the U.K., up 6%; West Germany, up 4%; and the Netherlands, up 23%.

According to Montedison, the figures indicate that the most important consuming markets are in a phase marked by a significant positive trend—noteworthy considering that 1988 itself had been considered to be exceptionally good.

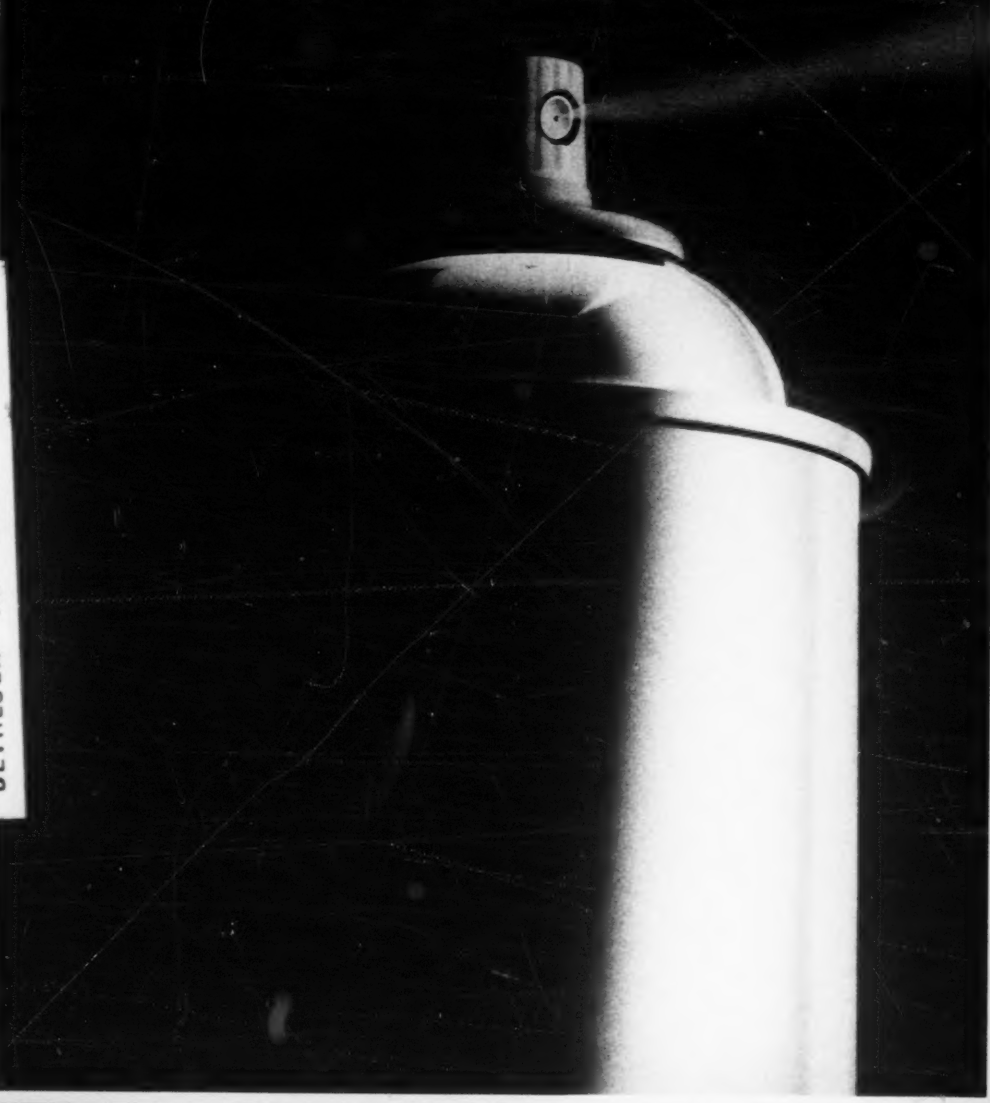
Moreover, if one accepts the argument that polypropylene sales are an efficient and sensitive leading indicator of general trends in the overall economy, the figures give an encouraging outlook for 1990. Lower growth rates than those experienced in the 1987–88 period seem to be in store, the company concludes, but the probability of a recession seems to be ruled out. January 1990 sales seem to bear that conclusion out: In the EC as a whole, January demand for polypropylene grew on average 16% over the same month in 1989. Similarly, in the U.S., demand in January grew 8% over that in January 1989, in turn up 7% over January 1988.

Patricia Layman

APRIL 23, 1990

CHEMICAL & ENGINEERING

NEWS



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Public attitudes, regulation push product innovation

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LETTERS

CHEMICAL SAFETY

Piranha solution explosion

SIR: We wish to report two violent explosions experienced with a sample of "piranha solution" used routinely in many laboratories to clean badly soiled glass frits and other surfaces.

At Berkeley an explosion occurred in a bottle of this mixture that had been stored for several days. In this case, the solution was prepared by carefully mixing approximately 150 mL concentrated sulfuric acid with 150 mL 30% hydrogen peroxide with cooling over 30 minutes. No difficulty was experienced during the preparation, and no incidents were encountered after the preparation while the solution was allowed to stand (we believe only loosely capped) in a fume hood. However, one week after the solution was prepared it detonated spontaneously in the hood, destroying the glass container in which it was stored, as well as other bottles of chemicals stored in the hood.

The other incident occurred several years ago at Cornell University. A graduate student was cleaning glass frits by a standard procedure of drawing small portions (about 20 mL) of a freshly prepared mixture of concentrated H_2SO_4 and 30% H_2O_2 through the frits by applying vacuum suction. This operation was eventually followed by washing with deionized water and finally acetone (keeping the different liquids separate). On this particular occasion, a violent explosion occurred, which shattered the heavy walled filter flask and caused multiple cuts in the face, chest, and forearms of the student. A partially lowered hood sash and appropriate clothing (safety glasses, lab coat, and heavy rubber gloves) provided some protection, but could not prevent the infliction of serious injuries. Subsequent questioning of the student led us to believe that inadvertent mixing of the highly oxidizing H_2SO_4/H_2O_2 mixture with an acetone residue (amounts unknown) was the cause of this accident.

At Berkeley, it is possible that an oxidizable organic material was somehow added to the bottle in which the solution was stored, or that the top of the container was inadvertently tightened. However, to the best of our knowledge neither of these things occurred. Furthermore, the force of the detonation makes it seem likely to us that it was due to a chemical reaction rather than simply to the buildup of pressure in the container. In any case, we feel that the most prudent interpretation of these events is that sulfuric acid/hydrogen peroxide mixtures are susceptible to spontaneous and unpredictable chemical detonation. Warnings in the literature that these solutions be handled carefully should therefore be taken especially seriously. We recommend that this mixture not be stored for any length of time, and if possible not be prepared or used at all.

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Cornell University

Having the ultimate secret

SIR: In the review of Jeremy Bernstein's book about high-energy physics (C&EN, Jan. 22, page 27), astrophysicist Richard C. Henry claims, "We chemists and astronomers already have in our hands the ultimate secret of the universe, for what it's worth. Certainly time did not exist before you became conscious, and it will end when you die. But most of us do not have the ego for this."

Ego, using its colloquial definition, has long been involved in pronouncements like these. About having the ultimate secret, John Heywood in the year 1598 remarked, "Every cocke is proud of his own dunghill." As for time existing only in the mind of man, are we to believe a rock ceases to decay progressively with time if we are not there to watch it? Samuel Johnson in 1793, when challenged by Bishop Berkeley's "ingenious sophistry" that matter exists only in the mind, "answered, striking his foot with mighty force against a large stone, till he rebounded from it—'I refute it thus.'"

Could it be that our earnest practitioners of high technology, having ripped off the lid of Pandora's box of nuclear energy, are at risk of becoming as unhinged as the box?

Miles H. Robinson
Santa Barbara, Calif.

Time to help

SIR: Wouldn't it be nice if Lewis J. Schupp's letter (C&EN, March 5, page 3) commenting that he is troubled by what he doesn't see happening in U.S. science and math education caused large numbers of scientists, educators, parents, and others to demand action—not more study and talk? This action requires the

More recently, Hollingsworth emphasized Hercules' commitment to developing its new technologies businesses such as advanced materials and liquid molding resins when he told C&EN it is "overwhelmingly important to address enterprise businesses—the longer term businesses that you get little immediate credit for." While he acknowledges his obligation to Hercules' public ownership base in terms of delivering immediate results, he also feels the stronger pull in guaranteeing his company a strong business and technology position in the years ahead.

As part of the effort to succeed, Hollingsworth points to Hercules' recent reorganization into eight business units. It is, he says, expected to bring about "profound changes from an organizational and cultural perspective," in the way Hercules runs its emerging businesses as well as its core businesses. The change, adds Hollingsworth, is meant to make the units "more market oriented, customer oriented and quality oriented." The move most of all should "create a greater sense of accountability among our people," and is ultimately "designed to take advantage of global opportunities."

Return on stockholders' equity should again approach 14 to 15%, says Hollingsworth. "It's in the cards. It's part of our business plan over the next few years," he says.

The problem for Hercules and Hollingsworth is to get more out of the company's existing core businesses so that they will contribute solidly to the bottom line as well as support emerging technology businesses. But that is more easily said than done. Hercules has had to shore up its core businesses in 1989 to the detriment of the bottom line: A new pale-wood rosin extraction process to update an 80-year-old line was delayed in coming on stream, and a failure to invest in wider web packaging film machinery lost tobacco industry packaging markets that new investments won't recoup until the first quarter of 1991.

Although some core business problems have been addressed, others remain. Hollingsworth believes he must better balance Hercules' portfolio of aerospace, chemical, and advanced materials businesses. He has succeeded to some extent, he believes, in rebuilding the chemical core with the purchase of Henkel's 50% interest in Aqualon.

Admittedly, the rocket motor propulsion aerospace business has done poorly in 1989. Hercules had to absorb the cost of rebuilding part of its Bacchus facility in Utah after a fire, but changes in government procurement procedures required Hercules, along with other defense industry contractors, to put more money into initial product development. The $323 million charge against earnings in 1989 was meant to put these difficulties behind Hercules.

The charges are expected to put Hercules' aerospace business on a more balanced footing vis-à-vis Hercules' chemical and advanced materials business, says Hollingsworth. Now that most of the huge investment in developing its aerospace propulsion business is out of the way, aerospace should figure less prominently in the company's capital outlays. Hollingsworth does acknowledge that aerospace will still be vulnerable to U.S. Congressional decisions on funding military and National Aeronautics & Space Administration rocket ventures.

To help balance large rocket ventures and the large losses they may engender, Hercules, in November 1988, bought a 20% equity in Orbital Sciences Corp. and is involved with that company in developing a low-cost commercial launch system for small satellites. The recent success Orbital Sciences had in launching a three-stage rocket from the wing of a B-52 bomber with a lightweight military payload bodes well for future commercial developments.

"We know advanced materials are not going to be immediately rewarding," says Hollingsworth. And while Metton liquid molding resins and other ventures are just developing—and while carbon fibers are showing a profit—Hercules will continue to support them. But the company's goal is to get its core portfolio of chemical and aerospace businesses in good enough order to finance its ventures in liquid molding resins, flavor and food ingredients, and other new technologies, says Hollingsworth. □

Southeast Asia seen as new U.S. trade area

The political changes taking place in Eastern Europe have focused some attention on the immediate future of U.S. trade with the region. But whatever changes in trading patterns may result from this "new market," they will only add to some substantial changes U.S. trade has already undergone between 1970 and 1988. Among these are a great rise in imports and exports in general and a shift of trade to the Pacific, particularly to Southeast Asia.

A brief analysis of the recent shifts in U.S. trade and the possibilities of additional shifts because of a number of European economic and political trends has been made by Jack L. Hervey, senior economist at the Federal Reserve Bank of Chicago. The current state of affairs is the result of events in the late 1960s, when the European Community and the European Free Trade Association were formed. At the same time, Japan was displaying an economic growth of 15% per year and the Kennedy Administration's round of tariff negotiations was drastically cutting tariffs. When this economic activity began, the U.S. dollar and investment abroad dominated international exchange. According to Hervey, the net effects of these events were elimination of the U.S. trade surplus and a shift of the U.S. trade balance into negative territory.

The dollar was devalued in 1972 and again in 1973. The Organization of Petroleum Exporting Countries quadrupled oil prices in 1973. Large quantities of dollars accumulated by Arab nations were recycled to Latin America and Southeast Asia. During the 1970s, U.S. exports increased by fivefold but its imports increased by sixfold, and the annual U.S. trade deficit averaged $26 billion. All of these events, says Hervey, set the stage for the new trade era of the 1980s.

The patterns of U.S. trade have changed with respect to geography and commodities. Canada is still the largest single trading nation for the U.S. However, Hervey says, its position in the U.S. trade picture is not so secure as it once was. In addition, in recent years Western Europe has become less prominent as a U.S. trading partner, with the volume of trade dropping from 34% of the U.S. total in 1970 to about 27% in 1988. Latin American trade has also declined slightly in the same period. Japanese imports increased 16-fold, however, and therein lies much of the friction between the two countries, since exports increased only 10-fold.

An unexpected change, Hervey notes, has been the abrupt rise of Southeast Asia as a trading partner. Singapore, Hong Kong, Taiwan, and South Korea together have emerged as a new trading bloc that exceeds in volume the combined trade with the U.K. and West Germany. In addition, other nations in Southeast Asia, including Thailand, Indonesia, and the Philippines, steadily provide another 2 to 4% of U.S. trade.

At present, Eastern Europe and China are not particularly significant to the overall U.S. trade picture. However, they have increased their share of U.S. trade from 1% in 1970 to about 3% in 1989. Imports from Eastern Europe have only been about 0.5%, but Chinese imports were about 2.5% in 1989.

The net effect of these changes is that the traditional market sources for U.S. imports have displayed declines in market share, particularly Western Europe and Canada. Similarly, the relative importance of Western Europe as a market for U.S. goods has diminished. In contrast, Southeast Asia has dramatically appeared as a market for exports and a source of imports. Hervey notes about 75% of all U.S. trade is conducted with Canada, Western Europe, Japan, and Southeast Asia.

Various commodity classes show U.S. export/import shift

	Exports		Imports	
$ Billions	1988	1970	1988	1970
Manufactured goods	$22.75	$ 5.07	$ 61.78	$8.44
Machinery	88.43	11.37	117.38	5.28
Transport equipment	46.78	6.52	79.87	5.88
Chemicals	32.36	3.83	19.86	1.44
Petroleum products	3.52	0.47	38.39	2.76
Crude materials	24.99	4.60	13.24	3.32
Food and live animals	26.27	4.34	20.29	5.40
Miscellaneous manufactures	24.67	2.56	70.61	4.84
Other	50.53	3.79	20.74	2.60

Source: Federal Reserve Bank of Chicago

There are corresponding changes in the commodities that are traded. Agricultural products are less important than they used to be, as are foods, live animals, and intermediate products. Chemicals and machinery have about picked up the slack.

Commodity exports to Canada shifted in favor of transportation equipment. Machinery exports to Western Europe also improved, mostly business machines and computers. Agricultural and intermediate goods dropped in volume, and chemical exports remained stable. Chemicals and intermediates exported to Japan also increased to 11% in 1988, and professional and scientific equipment doubled to more than 3% at the same time.

The shift in commodity exports to Southeast Asia, says Hervey, is indicative of the economic involvement of the area. Food-related commodities dropped from 18% in 1970 to 6% in 1988, while chemicals rose from 8% to 12%, with most other categories rising to a lesser extent.

Hervey notes that exports to other countries are often mostly in the form of foods, reflecting endemic problems of growing population and lack of an industrial base. However, other observers suggest that some Latin American countries—for example, Mexico and Brazil—are developing industries as rapidly as economics permit.

The shift in import patterns has been more pronounced than those of export patterns. Canadian imports are tending toward goods with a higher added value and there is a corresponding drop in crude materials. The share in imported chemicals from Western Europe nearly doubled, to more than 10%, but most of the other commodities dropped. The exception was machinery, which rose from 19% to 26%.

Japanese imports also have displayed a shift toward higher added value items. Automobiles increased from 14% of total imports to 33% between 1970 and 1988. Even more dramatic was the increase in imports of office equipment and computers, from 24% of the total to 45% during the same period.

Almost the same pattern is displayed by commodities imported to Southeast Asia. Business equipment and electrical equipment imports rose from 12% to 37%. The most unusual feature of the Southeast Asian import trade was the increase in heavy capital equipment and transport equipment. The gain was about 4%.

All in all, U.S. export trading partners have changed position, with Western Europe and Canada heading the list, followed by Southeast Asia, Latin America, and Japan. The import roster is headed by Western Europe, followed by Japan, Canada, and Southeast Asia.

The big lesson in this analysis, says Hervey, is that Southeast Asia has emerged as a distinct trading bloc and should grow even more in the near future. Southeast Asia has inexpensive labor to which high-cost production will migrate and which will support a higher trade volume.

The geographical groupings Hervey outlines appear to be "natural" and easily definable. However, the events in Eastern Europe, as well as the forthcoming Western European economic integration in 1992 could change things again. One of the great question marks is still China. Anxiety is growing over the role that Hong Kong will play after its reintegration with China and over the corresponding "econo-brain" drain from Hong Kong, some of which already is in progress. Despite all the difficulties, the attractions of a potential market of 1.1 billion people in China keep world traders focused on the Pacific. This may also temper otherwise increasing economic interest in Eastern Europe. The European markets are essentially consumer markets. In China, there is also a consumer market. But before it can be exploited, the markets for a national industrial and infrastructural base must be satisfied.

Joseph Haggin

Chinese to expand fuel industry to meet needs

Development of the Chinese petrochemical industry has reached a plateau. Following five years of internal building and the trauma caused this past June by the government's suppression of demonstrators at Tiananmen Square, the industry is ready to consolidate its gains and proceed. But whether it will achieve higher plateaus is questioned by some foreign observers, who view the country's limited domestic crude oil reserves as a major problem.

What the Chinese themselves believe was outlined by Hou Fusheng, an official with China Petrochemical Corp. (SINOPEC) at the 1st International Symposium on Technology of Petroleum & Petrochemical Industry, held in Shanghai late last year. The picture he painted is of an industry that has acquired its basic form and is looking to modernize as quickly as possible.

SINOPEC has been in business since 1983, when it was established by the country's State Council. As a state-owned corporation, it now controls most of the petrochemical production and oil refining in China. According to Hou, Chinese oil refining capacity has grown to 120 million metric tons per year, with the actual production being about 102 million metric tons in 1988. This was an increase of 27% over 1983.

Chinese refiners have invested heavily in the "deep refining" processes necessary for processing heavy bottoms and residues. Hou says about 41% of Chinese crude is now deep processed, 28% in fluid catalytic crackers and another 13% in thermal crackers. This meets present demand for light products. To further upgrade motor fuel production, SINOPEC employs viscosity-breaking, makes methyl *tert*-butyl ether additives, and uses hydrogen fluoride alkylation and catalytic dewaxing.

The demand that is forecast in gasoline and diesel fuels during the next few years assumes a growth of 6.5 to 7% per year. The demand is expected to reflect the need for higher octanes and high-quality asphalts.

At present, China has an oil shortage. Intense efforts are being made to increase domestic oil production through exploration and discovery of new reserves. But foreign estimates suggest that, for economic reasons, the reserves, though potentially great, will not be developed at the rate desired.

Petrochemical production in recent years has grown sharply because of the commissioning of new plants. Between 1986 and 1987, three new ethylene plants started operating at Daqing, Quilu, and Yangzi, according to Hou. Each had a nominal capacity of 300,000 metric tons per year. Ammonia and urea production were similarly increased, with new plants at Zhenhai, Urumqi, and Ningxia. Each has a nominal capacity of 300,000 metric tons per year of ammonia and 520,000 metric tons per year of urea.

Hou says in the near future SINOPEC will be redirected, with emphasis placed on the production of resins, fibers, and rubber. Most important will be an increase in production of fertilizers to meet the government's goal of self-sufficiency in foods. Planned production of each of these commodities is supposed to increase "severalfold" by the end of the decade.

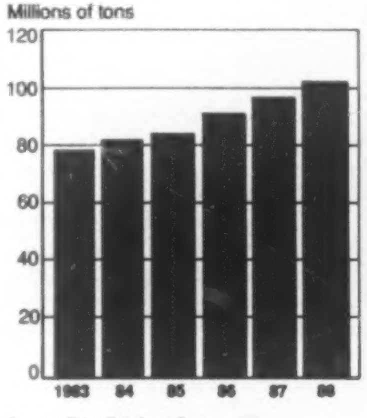
In outlining the expansion plans for the Chinese petrochemical industry, Hou acknowledged that a lot of cooperation will be required between Chinese and foreign companies. One optimistic sign, he says, is the renewal of discussions between a number of foreign lenders, most notably the World Bank.

In the area of refining, emphasis is being placed on further development of upgrading processes for heavy oils. Catalytic cracking, hydrocracking, coking, viscosity-breaking, and deasphalting will be particularly important. The goal is to maximize production of light distillates. Hou says that Chinese crudes have low metal contents, which simplifies processing. The Chinese want to produce gasoline research octane numbers (RONs) of 90 or more as soon as possible and to increase the amount of RON 97 gasoline as the top-of-the-line grade. Additives figure heavily in this effort.

At present, refineries are producing at about 90% of capacity, which means that any further increase in refinery production will require new refineries. Hou says when new refineries are built, they will probably be concentrated along the coast, possibly anticipating increased production from the offshore fields of the Luoxiao, Taiwan, and Jiangsu basins. He also notes that siting refineries inland will be done when and where other fields are found.

Joseph Haggin

Petroleum refining is up nearly 30% since 1983



Source: China Petroleum Corp.

Petrochemicals production has grown sharply

Metric tons, thousands	1988	1987	1986	1985	1984	1983
Ethylene	1111.0	818.9	586.6	555.1	551.1	556.9
Plastics	1026.0	726.0	565.1	487.3	485.2	482.4
Monomers	588.7	524.0	504.6	490.0	358.7	206.9
Fibers	347.9	326.9	313.5	306.4	241.2	174.0
Rubber	193.0	145.9	129.7	128.5	127.6	124.4

Source: China Petroleum Corp.

Bush's Science Adviser Discusses Declining Value of R&D Dollars

Despite apparent large increases to R&D funding, less "real" money is available for individual scientists, small science programs

By the numbers alone, it appears that federal funding for research and development has done nothing but rise steeply and steadily for the past 15 years, from $25.1 billion in fiscal 1976 to a projected $71.2 billion in fiscal 1991. Yet money for funding small science programs and individual investigators is in very short supply.

This paradox was one of the themes emerging from the American Association for the Advancement of Science's 15th annual colloquium on science and technology policy held in Washington, D.C., earlier this month.

Keynote speaker D. Allan Bromley reiterated his belief that President Bush's fiscal 1991 budget proposal (C&EN, Feb. 12, page 7) with its 7% increase for total R&D, 12% increase for nondefense R&D, and 8% increase for basic research is "an excellent budget for R&D in what is otherwise a very difficult budget year." However, he admits several areas of concern remain, with one very serious problem being the funding rate for grants at the National Institutes of Health and the National Science Foundation.

Bromley points out that during fiscal 1989, for the first time ever, the fraction of excellent, peer-reviewed new proposals that were actually funded by the two agencies fell below 30%. It is particularly unfortunate, he says, that this is occuring at a time when every effort is being made to draw more young people into scientific careers.

There are several reasons for the current plight of the individual investigator, Bromley says. One is that the rate of inflation for research in the physical and life sciences is rising at a faster rate than the consumer price index, and nonearmarked dollars for NSF and NIH have not kept pace. He also believes members of the scientific community are themselves in some ways responsible for the funding crunch. "For years," he says, "we argued for larger grants of longer duration." NSF and NIH heeded those arguments and in the process built up substantial "outyear mortgages" for themselves. A third factor is simple demographics. According to Bromley, "About 87% of all scientists and engineers who ever lived and worked in the U.S. are active today, while less than 4% of all citizens are still with us."

The effect of inflation of the research dollar was also noted by former AAAS executive officer William Carey, who said "the instinct to gloat over the elegant provisions for R&D in the new budget is rather abruptly suppressed if one looks carefully" at a table in the AAAS budget analysis that casts the R&D budget in terms of constant dollars. "If I can believe my eyes," he says, "the message is that in constant dollar terms we will be nearly $10 billion shy of the real level-of-effort we had back in 1967. And for research, excluding development, we are precisely where we were, measured by funding effort, back in 1967."

Bromley: many reasons for plight

That support for new research starts is at a near standstill despite "historic" new budget authority has not only left research universities in a state of shock, it has also had a del-

In real terms, federal R&D funds less now than in 1967

$ Billions	1991[a]	1990[a]	1989[b]	1988[b]	1972[b]	1967[b]
Development	$32.7	$31.9	$32.7	$33.3	$26.8	$42.1
Basic research	8.9	8.6	8.3	7.8	5.5	6.4
Applied research	7.9	7.7	7.7	7.5	9.0	10.4
R&D facilities	2.2	2.3	1.8	1.7	1.5	2.1
TOTAL R&D	$51.7	$50.5	$50.5	$50.3	$42.8	$61.0

Note: Constant 1982 dollars. a Estimate. b Actual. Source: "AAAS Report XV: Research & Development FY 1991" eterious effect on the peer review system, Carey contends. "One hears [loud complaints] from exhausted panelists of reviewers who rate proposals on merit, only to realize the hopelessness of the whole business where, in the end, only one in four approved projects has a prayer of having a cheque arrive."

"The system is out of order," Carey concludes. "It was designed to work in a rising research economy, and nobody can make it work the way it is supposed to under steady-state or ration-coupon conditions."

Rodney W. Nichols, executive vice president of Rockefeller University, noted another effect of the funding crunch on individual investigators. In the halcyon days of real rises in research funding, individual researchers could look to many different agencies for support. That is no longer the case. Pluralism is out the door, Nichols says, when one agency has a monopoly on support of a certain kind of research as is now the case. A researcher has no real alternative when a proposal is turned down. NSF is no longer in any position to fulfill one of its original purposes—funding meritorious proposals that didn't quite fit in with the missions of other agencies.

There seem to be no easy solutions to these problems, particularly given the federal government's recent emphasis on megaprojects, such as the space station, the Strategic Defense Initiative, the Superconducting Super Collider, and the human genome mapping project. Carey suggests that if projects such as these are to be funded, and he sees a considerable amount of merit in some of them, then "we ought to be prepared to cough up the revenues to finance them as special initiatives that are not wrapped into the normal R&D budget. Unthinkable though it may be, there's no choice but to introduce extraordinary R&D goals to tax policy."

Bromley urges formation of a "constituency" for science, telling of the need for scientists to inform their individual Representatives and Senators of the need for the national investment in science and technology and the importance of supporting the university infrastructure.

Janice Long

House panel's clean air bill viewed favorably

Earlier this month the House Energy & Commerce Committee moved with unexpected alacrity and voted out a clean air bill just days after the full Senate had approved its version. Floor action on the committee's bill is expected in early May.

Since neither body had been able to accomplish this feat in the past 13 years (the last time the law was revised), hopes are now high that clean air legislation will become law this year. This all depends, of course, on the outcome of the House-Senate conference committee. The conference committee is expected to go to work early this summer. Its debate is likely to be contentious and drawn out.

The House panel was able to act as quickly as it did because its two chief adversaries—full committee chairman John D. Dingell (D.-Mich.) and health subcommittee chairman Henry A. Waxman (D.-Calif.)—and their allies were able to work out compromises. First a deal was worked out on tailpipe emissions, then followed compromises on smog in cities, toxic industrial emissions, and finally acid rain. Dingell doesn't expect "that any of these compromises are going to be changed on the House floor."

The only issue remaining in contention is alternative fuels. And during floor debate, Waxman has vowed to resurrect President Bush's call for automakers to build 1 million cars a year by 1997 able to run on methanol or other fuels.

The House committee bill is generally being better received than the Senate bill. Environmentalists believe its urban smog provisions are tighter than those in the Senate version. And industry lobbyists are pleased with the bill's provisions on second-round standards for toxic air pollutants. As Chemical Manufacturers Association spokesman Jeffrey C. Van says, "The House bill comes closer to what we think would make a good, effective law."

The two bills are surprisingly similar, but there are some key differences. Both bills have similar compliance schedules for attacking urban smog. However, the House committee bill would give states the right to control smaller sources of pollution, and the Environmental Protection Agency would be required to impose federal implementation plans when states fail to develop or implement their own adequate attainment plans.

The first-round tailpipe emission standards are nearly the same in both bills, but the Senate bill would phase in one model year earlier (1993 instead of 1994). Tougher second-round standards would go into effect in 2004 if 12 of the smoggiest cities are not in compliance in 2001, according to the Senate version. But in the House panel bill, similarly tough standards would go into effect unless vetoed by EPA. The agency would have to argue that the standards were not technologically feasible, cost effective, or necessary.

Both bills would require industry emitting toxic pollutants to install maximum achievable control technology within 10 years, though the House bill applies to more and smaller sources. They are most divergent in what to do about the remaining, or residual, risk. The Senate bill would require sources to reduce the risk of cancer to nearby residents to less than 1 in 10,000. The House committee bill would have Congress revisit the issue 10 years after enactment and then legislate based on an EPA study. Or Congress could have the law revert to the "ample margin of safety" language offered by President Bush in his clean air proposals.

The two bills offer similar approaches to acid rain control. Both would halve sulfur dioxide emissions from power plants by the year 2000 and would freeze them at that level. How to achieve this and also ease the burden on Midwestern utilities and coal miners is where the two bills diverge. The House panel bill would use a credits system as an incentive for utilities to install scrubbers. Those that did could get more credits and "bank" those early reduction credits for use later should they want to expand. Scrubbers would allow for continued use of high-sulfur coal, thus minimizing job losses in the coal fields.

Lois Ember

U.S. Can's aerosol can plant at Derry, N.H.

Aerosol Product Innovation Fueled By Public Attitudes, Regulations

Susan J. Ainsworth, C&EN Houston

For those in the aerosol industry, there's no rest for the weary. Having recovered from a long battle with adversity in the late 1970s and early 1980s, aerosol producers and their suppliers enjoyed some healthy growth rates over the past several years. But now, because of mounting pressures from the public and from a variety of regulations, business is flattening out and growth is slowing again.

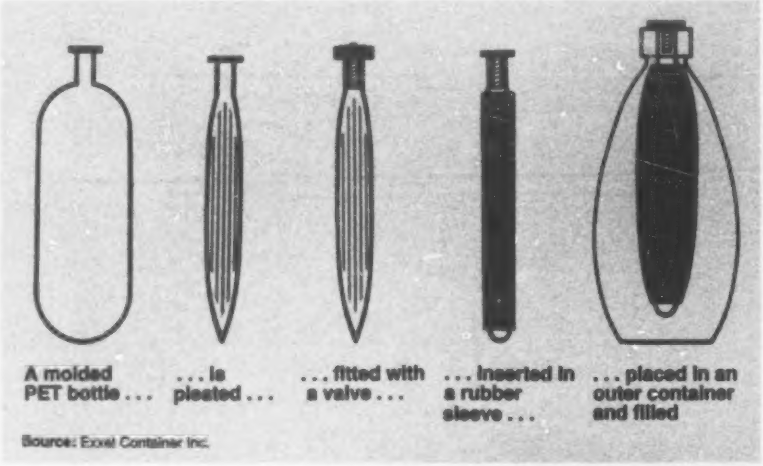
In the U.S., aerosol production was up 6.8% in 1988, according to the annual Pressurized Products Survey conducted by the Chemical Specialties Manufacturers Association (CSMA). However, next week when the 1989 survey is unveiled at CSMA's spring meeting in Chicago, some predict that it will show slower growth for aerosol products. "I think the survey will show growth of maybe a couple of percent if it is that much. One or 2% is more likely," predicts Jim Jandora, product manager for aerosols at U.S. Can Co., Oak Brook, Ill.

Likewise, in Western Europe, aerosol production has been slowing. In the U.K., one of the largest markets for aerosols in Western Europe, average annual growth hovered around 9% from 1981 through 1987, according to the British Aerosol Manufacturers' Association (BAMA). But growth in 1988 slowed to 1.6% and when the 1989 numbers come out, they will likely show that production declined 3 to 5%, according to BAMA director David Roberts.

Erosion of aerosol demand can be traced to several factors, but industry experts say environmental pressures from governing bodies and consumers top the list. "There's been a lot of undeserved bad publicity so I'd be very surprised if U.S. growth in 1989 turns out to be as high as it was in 1988," says Dick Frauenheim, president of Diversified Chemicals & Propellants Co. International, based in Channahon, Ill.

"Believe it or not, there are people out there that think that aerosols made in the U.S. still contain [chlorofluorocarbons]," despite the fact that they were banned with only a few exceptions in 1978, says Jandora. And there has been some un-

Nonaerosol package is gaining ground worldwide


A molded PET bottle . . .
. . . is pleated . . .
. . . fitted with a valve . . .
. . . inserted in a rubber sleeve . . .
. . . placed in an outer container and filled

Source: Exxel Container Inc.

The aerosol industry continues to suffer from negative publicity and a barrage of regulations. And as a result, some contend, marketers are eyeing other package forms so as to avoid these problems. One alternative package form that is gaining worldwide acceptance is the propellant-free Atmos container marketed by Exxel Container Inc., Somerset, N.J. "In some ways, we are a very big threat to the aerosol industry, but we realize that competing with it is going up against a giant," says Pamela J. Binder, Exxel's manager for marketing programs.

Atmos consists of an inner bottle of polyethylene terephthalate (PET), the same plastic used to make large soda bottles. The bottle is pleated into a narrow tube and fitted with a valve, inserted into a rubber sleeve, and placed in a larger container that can take on a variety of shapes and sizes to look just like any aerosol product. The contents are then injected into the bottle under pressure, expanding the bottle while stretching the rubber sleeve outward. The rubber's propensity to contract provides the pressure to release the product through the valve in a spray. "It's really quite a simple concept, but it also is unique," says Binder.

The container, which has been on the market since mid-1986, is catching on. Marketers in North America, Europe, and Japan are using Atmos to package dozens of products ranging from sun protection sprays to hair treatments and skin care products.

"Just within the past year, marketers that rely heavily on aerosols have begun major programs to examine alternatives due to the regulatory environment and consumer attitudes surrounding aerosols," says Peter G. Gould, president of Exxel. As a result of this trend, he says Exxel is "doing product experimentation with half the major aerosol users right now. That does not mean they all will adopt our system," but it has boosted the company's growth projections for Atmos almost overnight.

Still, the system may not compete with the aerosol in every product category. One industry source notes that Atmos has its drawbacks: "It sprays coarse and wet and some product ingredients are not compatible with the plastic packaging." Gould concedes that the container is not compatible with all solvents and product ingredients. For example, Atmos would not be a good package for oven cleaners or disinfectants, although it works well with a broad range of personal care products, he says. And he adds that Atmos' spray is wetter than aerosols, "because it is spraying pure product without the 10 to 30% gas per unit time sprayed from an aerosol."

There may be a glitch, too, in Exxel's campaign to promote Atmos as an environmentally friendly alternative to the aerosol, says another industry source. "While these packages don't rely on propellants, they do add to the landfill problem. Unlike metal aerosol cans, the plastics they are made from are not recyclable."

founded bad publicity about the issue surrounding volatile organic compounds (VOC), which started in California, according to Frauenheim. As a result of this kind of publicity, he anticipates "maybe some reluctance on the part of marketers to introduce new aerosol products," which will also limit growth.

In Europe, where Diversified CPC has become a major propellant supplier, misinformation and bad publicity are also taking their toll, especially in West Germany, where that sentiment is particularly strong, notes Frauenheim. Roberts agrees: Growth in the Western European market for aerosols has slowed, "because of the change away from CFCs and the adverse publicity," that that switch has attracted.

But aside from that factor, when the numbers are out, growth in 1989 is expected to have declined, partly because growth was unusually high in 1988, says Frauenheim. What took place in 1989 was normal market growth, Jandora contends. Last year was a "wait and see" period without the flurry of introductions that affected the market the way they did in 1988, he adds. "The market generally needs time for products to settle. Not everybody launches at the same time," says Jandora. "If the introductions had been spread out, the industry would have seen a more even distribution of growth. It's just a function of timing."

These factors, along with the slowing economy, should have had some negative effect on overall aerosol volume in 1989, says Frauenheim. "The U.S. economy in 1989 did not perform as well as we hoped it would. There was little inflation and no recession, but there was not a heck of a lot of growth either," he adds. And in the U.K., the slowdown in the aerosol sector can be attributed to "the turndown in consumer spending probably more than anything else," says BAMA's Roberts.

Still, on a world scale aerosol production is growing, even if it is growing at a slower pace. Some contend that the convenience of the aerosol will continue to be its saving grace. How have aerosols managed to weather the storms of controversy and massive reformulation over many years? "Because aerosols are safe and convenient, quick and clean, spill-proof, kid-proof, and there are certain applications that require the aerosol form," says CSMA president Ralph Engel. "It's probably the single most innovative package in the world and it's a package of choice of the consumer," he adds. For these reasons, aerosol industry players contend, the aerosol industry is here to stay.

That's good news for the chemical industry. The aerosol industry is a significant purchaser of chemical products—above and beyond the chemical contents of the products put into aerosol cans. For example, it consumes 293 million lb per year of hydrocarbon propellants, according to propellant supplier Aeropres, Shreveport, La. Aerosol hair sprays have boosted consumption of ethanol significantly over the past two decades. The industry sometimes needs high-performance linings for their cans. And many of the parts of an aerosol container are plastic, making these packages in turn a good customer of the chemical industry. Thus, the continued growth of the aerosol industry benefits the chemical industry as well.

Indeed, when CSMA's survey is unveiled next week, 1989 may well show up as the seventh straight year of real growth in units for the U.S. aerosol industry. According to the most recent CSMA annual Pressurized Product Survey, an estimated 2.91 billion aerosol container units were filled in 1988, up from 2.72 billion in 1987.

Citing the 1988 CSMA survey, Dan Minogue, chairman of the CSMA Product Survey Committee and vice president of sales at Precision Valve of Yonkers, N.Y., attributed the increase in 1988 to a number of factors. Some of that growth came from new product launches in the antiperspirant and hair spray areas, along with increased demand for hair sprays for today's changing hairstyles. In 1988 personal products were the largest U.S. category of aerosols, making up more than 37% of the total containers filled—some 1.1 billion units. And hair sprays made up the largest single product category broken out in the survey. The domination of personal products and hair sprays will likely continue in the 1989 survey, say aerosol industry players.

"Hair sprays have been a very large growth market for us," notes U.S. Can's Jandora. He points out that growth in that segment is a function of style, which currently calls for a very stiff hold. Back in the early to mid-1980s when mousses were popular, "we saw some softening in the hair spray market, but now hair sprays are on an upside," says Jandora. "The combination of hair spray and mousses was very big last year," says Frauenheim. "That was surprising because a lot of people thought that when the mousse came out it would replace part of the hair spray market." Instead, he notes, a teenager might use a mousse and then hold the style with a spray. "So the mousse has turned out to be a good combination product rather than a replacement for hair spray."

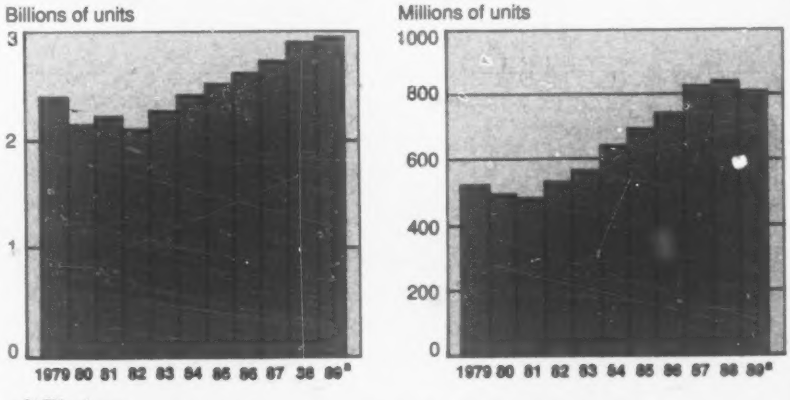
Growth for the whole hair fixative market, including retail and salon segments, shows no sign of slowing, according to Frank Nowak, marketing manager for cosmetic polymers at National Starch & Chemical. The company produces a broad line of resins used in hair care products worldwide.

In Europe, hair products also comprise a large segment of the aerosol industry as do deodorants and antiperspirants. But growth in sales of mousses for the hair and body has slowed, according to Fiona Leinster-Evans, marketing assistant for CMB Aerosols, Pangbourne, U.K., an arm of CMB Packaging, which was formed in late 1988 by the merger of U.K.'s Metal Box and France's Carnaud. "Hair mousse has become a commodity product now and is selling in larger packs," whereas before it was sold in "luxury packs," she adds. Buoying European aerosol growth in hair care has been a proliferation of products including spritzes, gel spray, hair cream, hair wax, shine spray, and conditioning spray, says Leinster-Evans.

And perhaps a good sign for continued strength for aerosols in the antiperspirant market in 1990 is

Production of aerosol units continued climb in U.S. . . .

. . . but fell off in U.K. last year



a C&EN estimate.
Sources: Chemical Specialties Manufacturers Association, British Aerosol Manufacturers' Association

Palletized loads of empty aerosol containers at U.S. Can's Racine, Wis., plant await

Helene Curtis Co.'s introduction early this year of its Degree antiperspirant and deodorant product. The Chicago-based personal care marketer is selling the product in solid and roll-on forms as well as in an aerosol package.

Says one industry source of the launch: "It's interesting that a company would introduce an aerosol antiperspirant with California poised to issue regulations that could affect its sale. That's a very bullish move from an aerosol standpoint." In response, says Andrea Saia, group brand manager for Degree: "Aerosols comprise about 20% of the antiperspirant market segment, and we want to capitalize on that segment." "Not surprisingly," she adds, "consumer demand for aerosol antiperspirants has been stable over the past couple of years, because they are the most convenient and hygienic form."

And in Europe, deodorant aerosols have continued to enjoy success. For instance, in the U.K., aerosol deodorants account for 65% of all such products, says Leinster-Evans. Meanwhile, pump deodorants have only 1% of the market.

Demographic changes with an increasingly aging population is resulting in a new group of consumers, notes Leinster-Evans. Demand for new products aimed at this market could boost growth in personal care aerosols. And a growing market for personal care products for men could have a similar effect.

A proliferation in eye care products also helped buoy growth in aerosols in the U.S. in 1988, says Minogue. For example, saline solutions have been packaged in spill-proof, contamination-proof aerosol cans for some time now. And the saline solution niche has created new demand for aluminum cans, which have been losing out over tinplate cans in the U.S. recently, notes one source. "If you put saltwater in a tinplate can it will just about decompose on you," the source adds.

Another factor that lifted 1988 growth for aerosols was continued growth in the automotive and industrial areas as professionals and do-it-yourselfers use aerosol products, says Minogue. One interesting innovation in the auto segment is the introduction of aerosol kits sold to auto dealers to use to clean clogged fuel injectors in new cars, notes Frauenheim.

In trying to assess how aerosols might perform in 1990, Jandora points out that aerosol growth could depend somewhat on the weather, strange as it may sound. "The aerosol industry is very closely tied to mother nature," he says. For example, a frigid winter means growth in the use of aerosols such as air fresheners, deicers, carburetor cleaners, and sprays for frozen locks. On the other hand, a wet spring and hot summer means more pests for consumers, who tend to buy more aerosol insect repellants.

The Lyme disease scare last year fueled the insecticide segment of the aerosol market, he notes. "And when we had that hot summer in the U.S. recently," he adds, "people tended to use more personal care aerosol products such as antiperspirants and hairsprays."

But perhaps more than any other factor, the fate of the aerosol industry rests largely on future regulation. Indeed, regulation has had a major role in shaping the U.S. industry to date.

For example, when CFCs were banned in the late 1970s, the industry was forced to reformulate its products and start a still-continuing public relations campaign aimed at educating the public about how aerosols affect the environment.

Research done in the 1970s showed that CFCs are not degraded under normal conditions, but persist to react with stratospheric ozone, breaking it down and destroying part of the ozone shield that surrounds Earth. The result is an increase in the amount of ultraviolet radiation reaching Earth's surface. The most obvious source of free CFCs was aerosol propellants, which were vulnerable because they were deemed convenience products that the consumer really didn't need. So in 1978, the Environmental Protection Agency and the Food & Drug Administration banned all fully halogenated fluorocarbons as propellants in nonessential aerosol uses, which make up about 98% of all aerosols filled in the U.S.

This legislation created a public controversy in the U.S. Consumers believed that all aerosols were contributing to the depletion of the ozone layer, even though more than half of the industry used hydrocarbons, not CFCs, as propellants. And, amazingly, more than 10 years after the ban, "there's an unfortunate misconception that aerosols are damaging to the stratospheric ozone layer. The industry [in the U.S.] now relies heavily on hydrocarbon propellants, which don't damage it at all," says Harry McCain, technical and safety director at propellant supplier Aeropres and vice president of the National Aerosol Association (NAA).

shipment to fillers

Ironically, it may be the publicity of efforts to further reduce CFCs production worldwide that has fueled public controversy about aerosols. "With the CFC ozone issue blowing up again relative to the [Montreal Protocol on Substances That Deplete the Ozone Layer] and reduction of CFCs in a variety of product forms, the media seized the opportunity to pound the same old message into the consumer. So we have a story to tell all over again," says CSMA's Engel.

The Montreal protocol, which became effective in January 1989, calls for a 20% reduction in production of CFCs by 1993 and a 50% reduction by 1998, based on 1986 levels. And the word is that that schedule may be accelerated when the parties bound by the international treaty meet in London in June to amend it. Most, if not all, parties agree that there is a need to eliminate CFCs by 2000.

These measures affect the shrinking volume of CFCs still used as propellants in other countries and the exempted aerosol applications in the U.S. More significantly, however, they are aimed at CFCs used in other applications such as air-conditioning, refrigeration, and foam blowing. In reporting about this accord, "the news media gave the erroneous implication that all aerosols produced in the U.S. still contain CFCs. Except for a few product categories, they do not, but the public simply didn't hear it that way," Frauenheim says.

Controversy is also brewing in Europe, where CFCs have been phased out more recently. For example, at the end of 1989, aerosol producers in the U.K. voluntarily decided to stop using CFCs. As in the U.S., the exception is vital medical and industrial needs, which account for about 10% of all aerosols in the U.K.

The European Community has issued recommendations calling for a swifter CFC phaseout than called for by the Montreal protocol. The commission is calling for reduction in CFC consumption by 90% of what it was in 1976 by the end of 1990. "There's a strong compulsion for BAMA members and the whole industry to adopt the commission's recommendation. My guess is that Europe will meet the EC target," says BAMA's Roberts.

Perhaps it is pressure from the European public that is speeding the change. "The erosion of the ozone layer has turned the consumer away from aerosol products with CFC propellants. This, in turn, has caused a decline in the production of aerosol cans," in Europe, says a study on the Cosmetics & Toiletries Packaging Market in Western Europe put out in the fall of 1989 by Frost & Sullivan, New York City. "Aerosol can production in West Germany dipped by about 12 to 15% last year as they were reformulating away from CFCs. Negative publicity hit that country the hardest; I don't think any of the other European markets suffered to that degree," says one industry source. But for his part, BAMA's Roberts says he is not witnessing a decline in can production in the U.K.

To be sure, there are many factors currently at work to ensure a speedy end to CFC production worldwide. One such factor—a new U.S. federal excise tax on stocks of CFCs that went into effect on the first of this month—may contribute to that effort. Manufacturers must pay $1.37 in tax for every pound of CFCs they make in 1990, escalating to $1.67 in 1992 and $2.65 in 1993. Importers must also pay tax on CFCs and all products that are made with CFCs that they bring into the U.S. The tax will essentially double the price of CFCs. For example, Du Pont sells its bulk CFCs for roughly $1.00 per lb. "As for how this new tax will affect aerosols, my impression is that producers in exempted categories will reformulate with a cheaper CFC substitute if they possibly can. But you have to assume that the reason the government exempted these applications is that they couldn't readily use some other propellant," says Tony Vogelsberg, environmental manager for Freon products at Du Pont.

The "essential" aerosol applications that are exempted from the CFC ban include medical products such as contraceptive foams and bronchial dilators, products used by the Department of Defense, food products containing F-115, certain uses in electronic/electrical and aviation industries, and certain pesticide uses. But Vogelsberg points out that this category only represents about 30 million lb of CFCs, or about 4% of the total U.S. CFC market. And, he predicts, by the year 2000 there will not be any CFCs in any product, referring to the likelihood that the Montreal protocol will increase the stringency of its phaseout program. "They'll be history. Aerosol producers will have no choice but to go to alternative products or alternative approaches," Vogelsberg adds.

Looming on the horizon has been another issue that the aerosol industry fears could take on the same weight and magnitude that the CFC issue had. The biggest perceived threat currently to the livelihood of the aerosol industry is the clean air issue, according to CSMA's Engel. "The challenge is to make the regulators and legislators understand that we can take drastic actions by getting rid of all consumer products with the wrong steps and thus put industries out of business without doing much for clean air. Or we can take the time to determine what steps we can take while maintaining commercially and technologically viable products," he says.

Although clean air legislative activity is taking place independently on federal and state government levels, proposals by the California Air Resource Board (CARB) have the most immediate repercussions and potential long-range impact, according to Albert L. Pellini, chairman of the board of CSMA and vice president of sales and marketing at Advanced Monobloc Corp. of Chappaqua, N.Y. CARB is considering legislation to control the use of hydrocarbon aerosol propellants—propane, isobutane, and *n*-butane—as part of its efforts to control the formation of smog (or ambient ozone) from VOC emissions. Fortunately for some aerosol producers, the amended California Clean Air Act prohibits CARB from adopting any regulations unless the regulations are technologically and commercially feasible and necessary. But these criteria apply only to consumer products.

For many years the industry as a whole has been trying to tell regulators that they may be barking up the wrong tree when it comes to trying to reduce smog problems in major U.S. cities. "If we stopped making personal care products and banned every aerosol on the face of the Earth, the fact is that it would probably not improve ambient ozone or smog conditions one iota," says Aeropres' McCain.

In a statement on aerosols and VOCs, NAA says: "VOCs and photochemically reactive compounds (PROC)—propane, isobutane, and *n*-butane—as utilized in propellant systems for aerosol packages simply do not make any significant contribution to atmospheric ozone pollution." NAA bases that contention on four main points.

First, "aerosol propellants are an infinitesimal part of the VOC/PROC emissions in the U.S," says NAA. Second, "aerosol propellants present a significantly lower order of chemical reactivity which does not influence or contribute to smog production," it adds.

Third, "both quantity and usage patterns do not allow VOC/PROCs from aerosols to impact air quality," NAA asserts. For example, "with a shave cream or a tub and tile cleaner, the hydrocarbon propellant is mixed with the product and tends to be washed down the drain with the product to be biodegraded. So these types of products do not affect smog formation," Frauenheim explains. Fourth, "any reduction or alterations in aerosols could result in alternative packaging forms which may have a negative impact on air quality," says NAA. One misconception, for instance, is that pump sprays represent a more environmentally friendly alternative to aerosols. But when it comes to VOCs, pump hair sprays, for example, rely on solvents such as ethanol, which is a much more reactive VOC than hydrocarbon propellants are, according to Frauenheim. And Aeropres' McCain asserts: "Hydrocarbon propellants are less tropospheric ozone-forming than ethanol—and many other VOCs used in formulations—by a factor of 50%."

To get these points across, NAA has formed a group to submit new information to CARB in an attempt to correct erroneous data on hydrocarbon propellants, says McCain. He laments that EPA is borrowing misinformation from CARB and adopting the same attitudes. "So we have a significant amount of reeducation to do to perpetuate the aerosol industry."

For its part, the CSMA Special Air Quality Committee has been "working for more than five years to provide California regulators with technical and economic evidence of the minimal contribution to the formation of smog from VOC emissions from underarm products" says Pellini. "We are making significant headway, too, not just with CARB, but with New York, New Jersey, Texas, and federally," adds Engel.

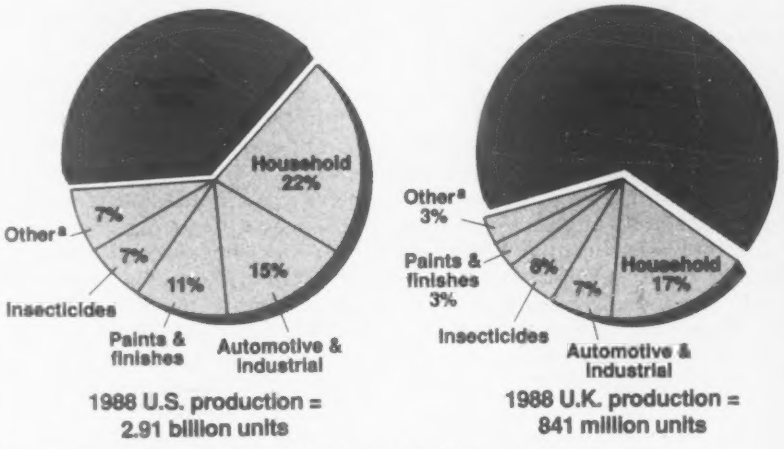
For example, CSMA says it was effective in promoting a realistic modification of New York Department of Environmental Conservation's proposal to reduce VOCs by 25% in insecticides, disinfectants, and air fresheners. As adopted, the proposal requires a four-year study of the environmental and cost impacts and feasibility of alternatives for reducing VOC emissions in those products, while maintaining product efficacy. A CSMA consortium of nearly 100 companies is conducting the study.

In Europe, "the VOC issue is not as strong as it is in the U.S. yet," says BAMA's Roberts. "But we anticipate that it will be in the not too distant future. What happens in the U.S. is likely to happen in our country only a little while afterwards."

Warehouse storage has long been a troublesome issue to the aerosol industry. "But this is now a concern to which the industry can respond technologically and has done so," says Aeropres' McCain. Basically, through CSMA efforts, the aerosol industry was able to modify guidelines of the National Fire Protection Association (NFPA) to make them "more livable for the industry," while preserving safety, says Frauenheim.

CSMA approached NFPA's Standards Council to suggest that its Code 30, which covers class IA flam-

Personal products dominate U.S. and U.K. aerosol industry



a Includes food products, veterinary and animal products, and miscellaneous categories.
Sources: Chemical Specialties Manufacturers Association, British Aerosol Manufacturers' Association

mable liquids, be modified to include a separate section pertaining to aerosols. At that point, "aerosols were treated more strictly than gasoline, because of the flammability profile of hydrocarbons," says David L. Fredrickson, chairman of the CSMA Aerosol Fire Testing subcommittee and senior chemical safety information administrator at S.C. Johnson Wax, Racine, Wis. "We needed to prove that while all aerosols act differently, they are not as flammable as their respective components, because they are blended and stored in metal cans, etc."

After spending 10 years and about $2 million, CSMA was able to demonstrate to NFPA that some guidelines were stricter than they needed to be. As part of that effort, CSMA and the National Paint & Coatings Association provided funding and expertise to conduct fire tests at a Factory Mutual Insurance research facility in West Glocester, R.I.

And under a NFPA Research Foundation program led by Factory Mutual, CSMA helped to develop new warehouse sprinkler technology. Compared with conventional systems, the early suppression, fast response technology is designed to "put out fires rather than just control them until the Fire Department arrives on the scene," adds Fredrickson.

"In any situation you can get to the point where something is regulated to be 100% safe, but you have to weigh the cost of those measures against the risks of something going wrong," says Fredrickson. He believes that the industry was successful in modifying these NFPA guidelines because the effort brought together professionals on all sides of the issue—insurance, industry, fire service, and wholesalers. And in coming up with a final document, NFPA considered, and adopted some, of more than 300 public comments, many from the aerosol industry. "Warehouse storage is a nonissue for the aerosol industry now and it is a success story for CSMA as well," says Engel.

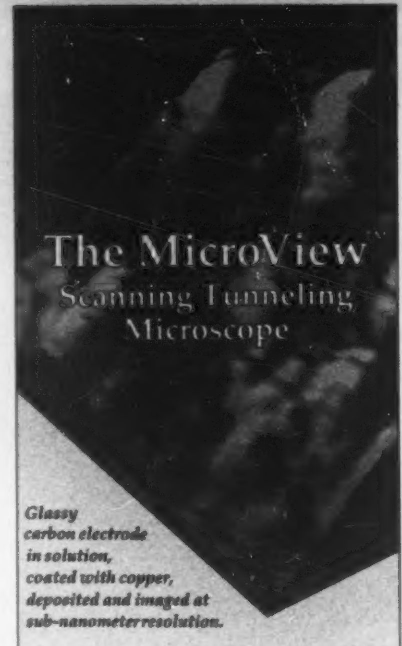
As in the past, regulations will likely be a major force in shaping the aerosol industry. Notably, the controversy over CFCs gave the final push to a switch to hydrocarbons. At the time of the controversy, hydrocarbons already were being used in some 55% of all aerosols filled because they were less expensive than fluorocarbons.

And since that shift, hydrocarbons have been the mainstay of the industry. The major suppliers of hydrocarbon propellants are Phillips 66 (Bartlesville, Okla.), Diversified CPC, and Aeropres. Diversified CPC bills itself as the world's largest supplier of hydrocarbon propellants now that it is operating its Krefeld, West Germany, plant, with its joint-venture partner Klockner & Co.

Growth of hydrocarbon propellants in the U.S. is hovering around 6% per year for the 1989–90 period, outpacing the aerosol industry itself, according to Aeropres. For its part, Diversified CPC's Frauenheim says his company's business is growing faster than the aerosol industry overall both domestically and in Europe, mostly because "we've developed more market share in Europe and in the U.S. Plus, we've been very active in exporting our products to Puerto Rico, the British West Indies, and the Bahamas." The mousse and new piston technology—which allows the dispensing of very viscous compounds via aerosols—have been growth areas for Diversified CPC, he says.

And because Diversified CPC was able to be in the right place at the right time with its Krefeld plant, it has been able to take advantage of growth in hydrocarbon propellants in Europe. Fluorocarbons were still being used widely when the Krefeld plant was being built, so the company was in place "to take advantage of the switch away from CFCs."

In addition, when Diversified CPC built the plant, it was the most modern hydrocarbon propellants plant built in many years. That helped the company attract customers in the high-value product categories—cosmetics and colognes, for example. "When we were just completing our plant in 1986, we anticipated that we'd be able to tap a certain amount of new growth each year as the new guy on the block. But we've grown dramatically every year and we are well ahead of schedule as far as our planned sales for Europe," says Frauenheim.



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A decade ago, hydrocarbon propellants took center stage because they, unlike CFCs, did not cause damage to the ozone layer. And hydrocarbon propellants have another thing going for them: They cost only cents per pound compared with dollars per pound for other alternatives. But for one reason—flammability—they are not safe for every application and they are expensive to store.

That's where hydrochlorofluorocarbons (HCFCs) came into the market, for what will likely turn out to be a short visit. These propellants generally are less flammable than hydrocarbons, and they have ozone depletion potentials of only about one twentieth of CFCs. Because these compounds contain hydrogen, they are less stable so that they break down in the lower atmosphere before reaching the stratospheric ozone layer. By mixing HCFCs and hydrocarbons, for example, one gets a formulation that is less flammable than hydrocarbons alone and more ozone-friendly than CFCs. In December 1982, with these benefits among the selling points, Du Pont introduced a new line of propellants under the Dymel trademark. The line included HCFC products 22 and 152. But with renewed interest in the elimination of CFCs and other halons that threaten the ozone layer, HCFCs also are coming under fire.

Chemistry

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"When we introduced Dymel it was largely a program for us to take advantage of the 1978 CFC regulations," notes Don Dunn, market manager for aerosols at Du Pont. While the company found market penetration slow at first, business began to pick up in early 1986 "and there appeared to be some opportunity for us in Dymel." But shortly afterward, the ozone controversy was reactivated and "it really hit hard," he adds. Clearly, now there's a desire to further reduce CFCs by the middle of the next century and to get rid of mimimal ozone depleters such as HCFCs as well, he points out. "So, what we viewed as an opportunity for growth of HCFCs like 22 has largely disappeared as HCFCs are no longer viewed as environmentally acceptable."

One last bastion of opportunity for HCFCs in aerosols is in replacement of CFCs for government-exempted "essential uses," notes Dunn. In exempted applications where CFC-12 is used for nonflammability reasons, there is already significant conversion to HCFC-22, he adds. However, he does not see short-term substitution options for products that now rely on CFC-113 or for pharmaceutical applications. "Reformulating medical aerosols requires much toxicology research and redevelopment, so that is one area that will probably continue to use CFCs until late this century."

Because HCFCs are still ozone depleters, "they are considered only bridge compounds to long-term HFCs that do not contain chlorine," says Dunn. "Getting to HCFCs was one step. Getting to HFCs is a lot more difficult, because it requires a much more complex manufacturing process," he explains.

ICI and Du Pont are among the companies that have come up with HFCs and are poised to produce them on a commercial scale. Dunn anticipates that it will be the mid-1990s before the industry is ready to supply the larger markets.

Engel: aerosol is package of choice

According to ICI Americas chairman Ben Lochtenberg, HFC-134a has potential in the aerosol industry, but it will be considered after the larger markets, when ICI's plants in Runcorn, U.K., and St. Gabriel, La., come on stream over the next two years.

Although Du Pont has lowered its expectations for the HCFC compounds in its Dymel line, its Dymel A dimethyl ether (DME) propellant shows promise. The major selling point for this propellant is its solubility in water, which is cheaper and more appealing from a VOC standpoint.

Du Pont brought DME to the marketplace in 1986 using an existing facility, notes Dunn. "And so far, growth in the U.S. has been slow to say the least," he says. "In contrast, DME has found good acceptance in Europe where growth has been quite rapid."

The reason for Du Pont's DME success in Europe may be another case of being in the right place at the right time. Dunn explains that DME became commercially available at the time that Europe was reformulating away from CFCs. In contrast, when the U.S. converted its aerosol formulations, DME was not an option. With all that reformulation behind them, few U.S. companies are willing to adopt a new propellant, which is generally more expensive than hydrocarbons, Dunn conjectures.

DME is finding wide acceptance in Europe in the hair care market for higher priced, high-performance salon products. For example, DME can be used in formulating water-based hairsprays, which are becoming increasingly popular, according to Dunn. To further capitalize on this market, Du Pont subsidiary Conoco is building a new DME plant at its Humber refinery in northeast England, with completion set for the end of this year. Du Pont already has a major production unit for DME near Charleston, W.Va.

And the DME market in the U.S. is looking brighter. Demand could rise in the U.S. and elsewhere if expected amendments to the Montreal protocol include controls on methyl chloroform, notes Dunn. "In the absence of another nonflammable chlorinated solvent, formulators may start looking at water-based systems, he says. And, depending on how the VOC regulation shakes out, DME may become more popular for its compatibility with water, notes National Starch's Nowak.

Indeed, environmental pressures are limiting the kinds of propellants that marketers can choose from in formulating their products. That fact has given life to nonaerosol packages such as the Atmos container marketed by Exxel Container Inc.

But some in the industry say the propellantless-pump is not regaining the strength it had in the U.S. during the last wave of public awareness over the CFC issue. Basically, consumers did not like the wet and heavy sprays from pumps and perhaps they haven't forgotten the experience, suggests one industry source. "In the late '70s, we saw consumers go to the pump, and most of them came running back to the aerosol, including my daughters," says Frauenheim.

In Europe, demand for pumps seems to be poor, too. Hairsprays in pump packs have had some success. Clairol Finale has been the most successful pump hairspray and has over 3% of the market, says CMB's Leinster-Evans. However, she adds: "Early research from West Germany indicates that repeat purchases of pumps are poor and the aerosol industry is regaining sales lost to pumps."

Aerosol manufacturers are also focusing R&D on developing an aerosol system that will enable compressed gases to be used as more effective propellants, she says. For example, late last year CMB launched its Horizon package, which is a new twist on the compressed gas aerosol. Through this package, CMB claims to have solved three problems with conventional compressed gas packages: variable

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flow, wet spray, and the lateral effect, the lack of spray when a can is held at certain angles.

In another R&D push, some companies including CMB are involved in extending the utility of the bag-in-the-can, which has been around for many years. In this system, product sits in the bag separate from, but completely surrounded by, propellant. Because the propellant does not mix with the ingredients, it is possible to dispense viscous formulations such as caulk, gels, and pastes. Initially, nylon was the only choice of bag material. But now CMB is offering bags made of five-layer laminated plastic and low-density polyethylene, which it says widen the range of items that can be packaged in this manner.

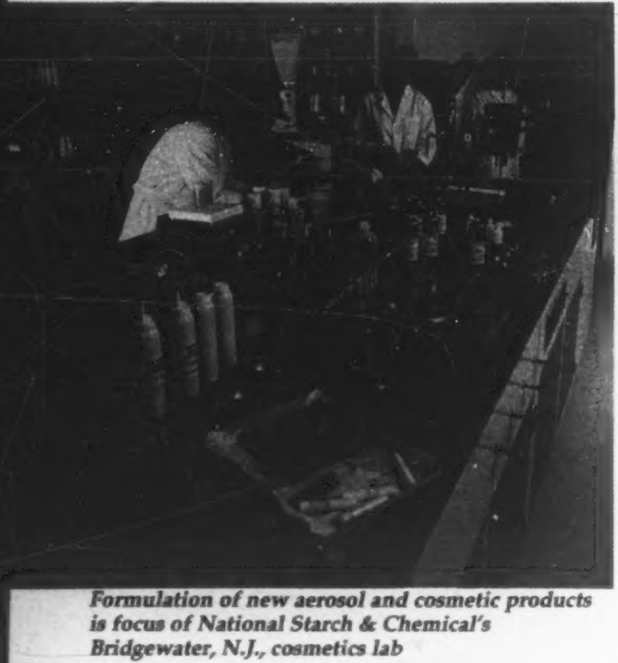
The trend toward the high-style, slimline can, which had its birth in Europe, continues to pick up pace in the U.S. This can features a neck that is tapered just a bit, so that when the cap is put on, it makes a smooth line from top to bottom. There is no ridge where cap meets can.

"The necked-in can has come into the aerosol industry in waves," says U.S. Can's Jandora. First, the personal care marketers adopted the style, which is more fashion-oriented, he says. "Now, we are starting to see them in household products such as glass cleaners and furniture polishes."

Indeed, in the 1990s Europe is destined to become an even greater force in the worldwide aerosol business. For one, the formation of a single, harmonized European market by the end of 1992 could make the U.K., Europe's largest aerosol market, even more dominant. For the U.K., 1992 likely will bring "a larger export market initially," predicts BAMA's Roberts. "We will have to face imports, but because the U.K. market is the largest in Europe, we should well more than compensate with exports. We should be able to play that [dominance] very strongly," he adds.

And Europe, with its collective strength could be a greater threat to the U.S. aerosol industry. Engel points out that while Europe is working toward a more unified marketing system, the U.S. is "doing just the opposite." Europe is breaking down barriers and harmonizing rules to allow for the easy sale and transportation of goods across borders. "We, on the other hand, in what was originally called new federalism, have shifted to a state-by-state regulatory approach. The result is a patchwork quilt of regulations that are going to break down the system of distribution in this country and make us noncompetitive."

Because some consumer product marketers produce their products at plants that serve more than one state, a change in one state's requirements could have a significant impact on the total market. For example, if a company must reformulate its products to meet California VOC regulations, it then has to decide whether to reformulate all of its products or produce separate products for that one state. "It becomes a question of whether a company is able to condition itself for that geographical market alone," says Du Pont's Dunn.



Formulation of new aerosol and cosmetic products is focus of National Starch & Chemical's Bridgewater, N.J., cosmetics lab

For the U.S. to remain competitive in the world, "we need to realize that there are appropriate times for the federal government to preempt state activity," Engel says, adding: "We have such a marketing edge in the world, what a shame to shoot that down and let the world take us over."

Some industry observers expect that Eastern Europe may also become a magnet for U.S. aerosol investments in the 1990s. Changes in this part of the world may well open the door to new growth opportunities for western companies. Diversified's Frauenheim points out that Eastern European companies currently make some aerosols, but most of the processes are based on older technologies.

"We had a booth at the International Aerosol Congress in Nice, France, last fall and I was amazed at the number of representatives from Eastern European companies that stopped and showed a lot of interest in aerosol manufacturing and hydrocarbon propellants, in particular," Frauenheim says. But while the demand for westerners' range of products and technologies exists, one of the drawbacks to investment in this part of the world is obviously their currency, he says.

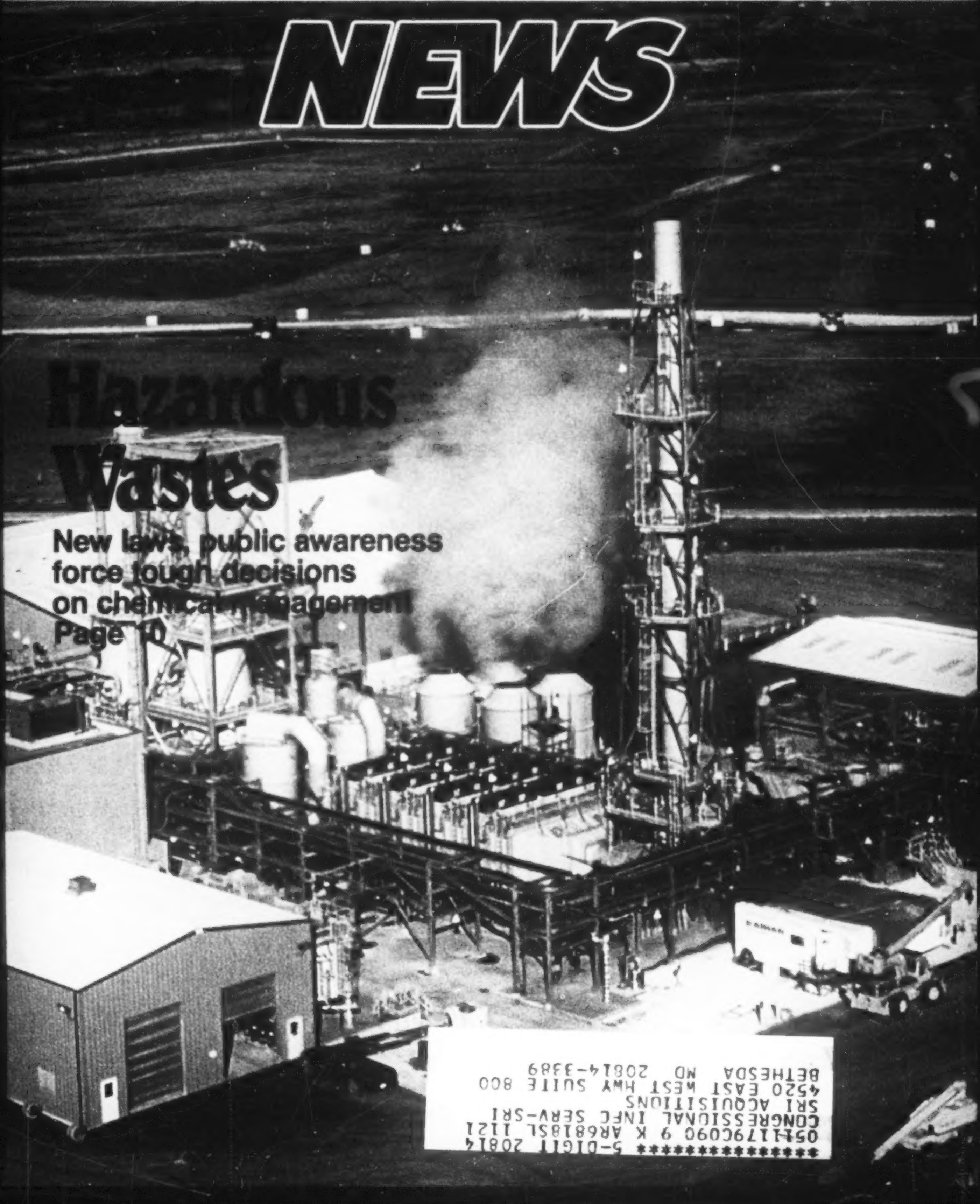
Separately, some industry observers anticipate that the 1990s will be another decade of reformulation. National Starch's Nowak anticipates that demand for "natural" raw materials will intensify because of public concerns over animal rights and the environment. This could mean a trend toward more water-based formulations, for example.

"Reformulation of aerosols will occur to allow for the aerosol package to exist," says Engel. "We have an obligation to do our fair share, but only our fair share, to clean up the air and that will undoubtedly require some aerosol reformulation." The aerosol has been a package under siege for many years, but it continues to weather these storms simply because the consumer wants it. And looking into the next decade, Engel adds: "The aerosol industry will continue to grow and consumers can be confident that they are using a package consistent with the environment." □

APRIL 30, 1990

CHEMICAL & ENGINEERING

NEWS



Hazardous Wastes

New laws, public awareness force tough decisions on chemical management
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CHEMICAL & ENGINEERING NEWS

APRIL 30, 1990

News of the Week

- **Earth Day activities included many by chemical industry although its involvement was decried as a "greenwash" campaign by some environmental groups.** Page 4
- **NAS elects 60 new members, and 15 foreign associates, several of whom are chemists.** Page 6
- **Labor Department report calls for better petrochemical industry safety plans that would reduce potential for catastrophes like the Phillips 66 disaster last fall.** Page 6
- **Dallas investor Harold Simmons to sell stake he controls via NL Industries in Georgia Gulf.** Page 7
- **President Bush addresses NAS's annual meeting, the third president in this century to do so.** Page 7
- **New series of synthetic sweeteners were developed through rationally planned research and computer design methods.** Page 8
- **Du Pont's new amorphous fluoropolymers exhibit enhanced physical properties.** Page 8
- **ACS Boston meeting, which attracted more than 13,000 attendees, highlighted theme of educating future scientists.** Page 9

Business

Agricultural biotech firm, Mycogen, will soon bring to market a new generation of biopesticides that it claims are as effective as chemical pesticides but safer to the environment. **Page 18**

Outlook for propylene prices depends on demand for polypropylene, which accounts for nearly 40% of U.S. use of the monomer in chemicals and polymers. **Page 21**

Government

Congress is busy setting 1991 budgets for various federal agencies, after returning from its Easter recess. **Page 24**

Education

Conference on freshman year in science and engineering affirms that research-oriented science faculties have a duty to contribute part of their time to improving the teaching of science. **Page 27**

ACS News

Committee on Professional Training reports on 1989 bachelor's, master's, and Ph.D. graduates of ACS-approved schools; University of California, Berkeley, and Indiana University are top producers of Ph.D. chemists. **Page 29**

Cover: Chemical Waste Management's new rotary kiln incinerator at Port Arthur, Tex., is the largest commercial unit of its kind in the U.S. Photo courtesy of Chemical Waste Management

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News Focus

Managers of chemical firms face rising pressure from local environmental groups, growing antiwaste legislation, and the need to find new disposal methods in their efforts to meet hazardous waste rules. **Page 10**

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LETTERS

CHEMICAL SAFETY

Solvent extraction hazard

SIR: This letter calls attention to a hazard associated with the environmental analysis of water samples requiring solvent extraction using separatory funnel technique.

In the analytical determination of chlorinated phenoxy herbicides in water, the following extraction procedure was being used. A 1-L well water sample (laboratory reagent blank) was acidified to pH 2 with phosphoric acid. Then 60 mL methylene chloride solvent was added. The glass stopper was placed on the 2-L separatory funnel and inverted. Immediately upon inverting, before venting could take place or any shaking had begun, the flask literally exploded, sending glass through the chemist's clothing into his chest, cutting an artery and several veins. Both internal and external stitches and cauterization were required. The chemist has recovered; however, the accident could have been much more severe.

This type of extraction has been done for nearly 20 years at our laboratory without incident. In summary, a word of caution to all chemists that even the most routine analysis whenever glass and pressure are involved can become very hazardous when the unexplainable occurs.

Ray E. Kelling
North Carolina Department of Environment, Health & Natural Resources, Raleigh

Methanol as fuel

SIR: The diatribe of Charles R. Sloan (C&EN, Dec. 4, 1989, page 57) against the use of alcohols, particularly methanol, as auto or diesel fuel is fascinating. He integrates into this small part of technology's almanac—not 365 days of next year's unknown weather—but almost as many predictions at the fringe of truth or possibility. His one firm, unassailable conclusion is: no good.

The author of the book ["New Transportation Fuels: a Strategic Approach to Technological Change"] is correct, indeed—despite Sloan's carping criticism—in that fuels do possess an attribute that does give power to engines that are designed to use it. Methanol has this chemical attribute. It produces somewhat less energy than does gasoline, but it has a greater efficiency of producing power to a greater extent than gasoline. Methanol's attribute produces in most, if not all, automobile-type engines more power than does gasoline because of methanol's much greater efficiency in combustion.

This greater power that methanol develops in an automobile-type engine of almost any size and weight led to a recent personal survey showing that top racing cars for a generation all have burned methanol instead of gasoline. Possibly equally important among the great attributes (usually called properties) of methanol that have persuaded auto racers of the greater power methanol provides are its far greater safety when used as a fuel (i.e., the lives of drivers it has saved in crash-burns), and the much longer working life it gives to the very expensive, overworked racing engines.

Sloan's basic misconception of fuels, the industry of their manufacture, and their use in transportation is his obliviousness to the indisputable economic fact that manufacturing processes of fuels and other processed materials lose gross weight, cost money to operate, and lose much of the gross heat of the raw fuel in the production and refining of a fluid fuel in a form that can be burned most efficiently and economically in some special mechanical machine.

No one has developed a passenger car with a carburetor to use crude oil, untreated oil shales or tar sand, or even coal dust. Thus there must be a physical and/or chemical conversion of the fuel as mined to produce a fuel usable in any engine that man has been able to devise so far in a full century of attempts. Much of the potential heat of the raw fuel always will be lost—just as the entropy of the universe always will be increased.

Sloan brings no solution. He only weeps bitter tears because fuel processing adds to the entropy of the universe, and manufacturing processes will never be 100% efficient. If Sloan were correct, one would not peel an orange or remove

Correction

• April 9, page 26: Pierre C. Hohenberg of AT&T Bell Laboratories developed density-functional theory, not Charles M. Hohenberg, as stated.

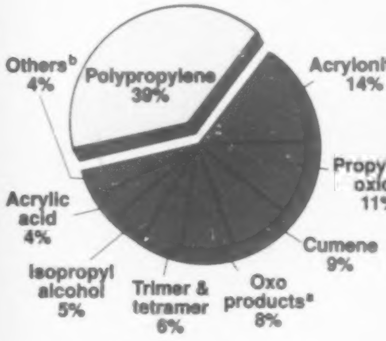
Propylene price outlook hinges on polymer use

Merchant suppliers of propylene this week will try to add 0.5 cent to May contract prices. If they succeed, prices will be 15.5 to 16 cents per lb for polymer grade. Their success will depend on a price increase for polypropylene, which accounts for almost two fifths of U.S. consumption of propylene in chemicals and polymers.

Following the rapid decline in propylene prices during the last half of 1989 and an inventory liquidation of polypropylene, prices firmed in early 1990 as a result of perceived tightness in supplies. This tightness was caused by temporary shutdowns of plants damaged by unusually cold weather. Prices for propylene, polypropylene, and some other propylene derivatives have been volatile recently because of the difficulties that suppliers have had maintaining announced price increases.

The lost production now has been made up, industry sources say. Consequently, factors other than short-term supply will continue to dominate prices unless another major upset in plant operations occurs. Modest growth in U.S. demand for propylene and derivatives in 1990 will be heavily influenced by inven-

Polypropylene dominates nonfuel uses of propylene



1990 consumption[c] = 21 billion lb

Note: Percentages are derived from reported production of chemicals and polymers. a Includes *n*-butyl alcohol, 2-ethylhexanol, and isobutyl alcohol. b Includes allyl chloride (most of which goes into epichlorohydrin), ethylene-propylene elastomers, and acrolein. c Forecast.
Source: C&EN estimates

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tory building and exports of polypropylene, sources add.

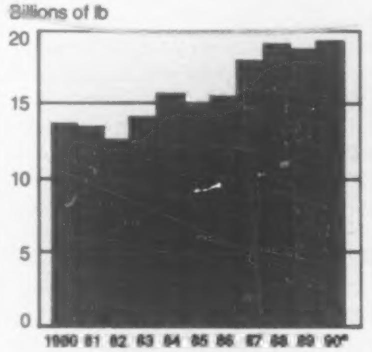
Supply of all grades of propylene could increase this year. Polymer-grade (typically 99.5%) propylene supplies will grow from both additions to steam cracker capacity and expansion of purification (splitter) capacity to raise purity of chemical-grade (typically 95%) propylene or refinery-grade (50 to 70%) propylene. Building of supply will depend on how much chemical and polymer users of propylene are willing to pay to compete for propylene that could be used in gasoline components or burned as fuel in refineries and elsewhere. The volume of propylene produced in refinery catalytic and thermal cracking processes exceeds the volume from steam cracking by severalfold, points out Michael Horvath Jr., manager of Petrocon Associates' Houston office.

Because the cost of feedstocks to refineries and steam crackers basically depends on world crude oil prices, propylene selling prices eventually relate back to crude oil prices. With the recent sizable declines in crude oil prices (reflected partly by declines in wholesale gasoline prices), propylene prices clearly are under pressure, Horvath says. Pressure on propylene prices is forecast to continue well into the third quarter, when demand for fuels normally rises, and will continue until overproduction of petroleum in the world is reduced.

Growing demand for polypropylene potentially could provide an impetus to stronger propylene demand and prices. More than 500 million lb of capacity to make polypropylene is scheduled to start up this year, and more than another 1 billion lb is scheduled for 1991. These polypropylene capacity expansions could add more than 20% to the capacity that was operating at the beginning of this year. However, the developing overcapacity will put pressure on prices of polypropylene and in turn on propylene.

Despite the capacity expansions, polypropylene demand will grow less than 5% this year and next, according to sources. The demand growth could be much less if exports again decline substantially. In 1989 exports fell 12% to about 1.4 billion lb. If the large amount of polypropylene capacity scheduled to start up outside the U.S. produces material as expected, exports from the U.S. could be replaced by local production unless these sales are made up in new markets. As a result, more pressure on prices will occur, causing polymer producers to ask for lower feedstock costs.

Propylene produced for nonfuel uses to set record



Note: Not all propylene produced for nonfuel (chemicals and polymers) uses is reported. a Forecast. **Sources:** International Trade Commission, National Petroleum Refiners Association Petrochemical Committee, C&EN estimates

Largely because of the growth in demand to supply polypropylene expansions, propylene consumption for making chemicals and polymers in the U.S. this year will increase about 5%, to about 21 billion lb. No sizable use of propylene will grow that fast except polypropylene. Therefore, the share of propylene consumption by polypropylene will increase faster than all others except very small uses, says an industry source. Even so, it is unlikely that polypropylene will reach half of propylene consumption by the end of the decade.

Acrylonitrile is a distant second to polypropylene as a consumer of propylene. The outlook for growth in this use depends heavily on the demand for acrylic fibers, which has varied with fashion and economics. Other polymeric uses of acrylonitrile (such as acrylonitrile-butadiene-styrene, styrene-acrylonitrile, and nylon resins) will grow slowly overall and will have little effect on propylene use.

Bruce Greek

ACS Committee on Professional Training 1989 Annual Report

Summary of data from departments offering an ACS-approved program, 1985–89

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates[a]	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1985	579	9679	4021	5658	316	1621	186	1806
1986	580	9295	3892	5403	315	1620	187	1885
1987	582	8848	3663	5185	316	1636	188	1936
1988	584	8372	3453	4919	319	1584	192	1955
1989	593	8122	3382	4740	318	1703	189	1967
CHEMICAL ENGINEERING[b]								
1985	123	6442	6442	—	118	1489	104	418
1986	118	5229	5229	—	116	1244	103	460
1987	107	4435	4435	—	103	1078	90	533
1988	128	3524	3524	—	124	1036	106	603
1989	110	2821	2821	—	108	876	90	553

a Includes graduates certified in approved options. b Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society decreased 3% in the 1988–89 academic year. This was the smallest decrease in four years. The number of master's degrees from these departments increased 7.5% after a decrease of 3.3% last year. The number of Ph.D. degrees continued to increase for the 11th year in a row. The increase was 0.6%.

The percentage of baccalaureate graduates certified to ACS was a little over 41%, about the same as previous years. (Certified graduates are those who have completed the curriculum specified by the Committee on Professional Training and are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation and full members after three years of professional experience or a higher degree in a chemical science.)

A total of 2118 of the baccalaureate graduates from the approved schools were reported as planning to go to graduate school, and 1637 reported plans to go to professional schools.

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1988–89 by departments whose undergraduate chemistry programs are ACS approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers and the Accreditation Board for Engineering and Technology. (Note: These departments are not required to report their data to CPT, so the number of departments included varies each year.) Included for the fifth year is a table with information on graduate student enrollments in chemistry departments whose undergraduate programs are ACS approved.

The number of bachelor's degrees in chemical engineering from the 110 AIChE-ABET-accredited departments that reported in 1989 decreased 19% from the total reported by 128 departments in 1988, the sixth decrease in a row. At the graduate level, the number of chemical engineering master's degrees decreased for the fourth year in a row and Ph.D. degrees decreased for the first time in 10 years. The number of master's degrees was down 15% from 1988, and the number of Ph.D.s was down 8.3%.

The chemistry programs at ACS-approved schools normally are reevaluated at five-year intervals. There were 593 colleges and universities on the approved list at the end of 1989. During the year the committee studied the chemistry programs of 223 of the approved schools and of 11 schools applying for ACS approval. Each evaluation

Summary of totals from 1989 reports from departments offering an ACS-approved program

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, Total	593	5025	3097	8122
Certified		2120	1262	3382
Noncertified		2905	1835	4740
Masters	318	1076	627	1703
Doctorates	189	1458	509	1967
CHEMICAL ENGINEERING				
Bachelors, Certified	110	1977	844	2821
Masters	108	709	167	876
Doctorates	90	481	72	553

involved a review of extensive documentary materials submitted by the department chairman describing the current status of the program.

Three schools were added to the ACS-approved list by the committee in 1989; two were put on probation; three were removed from probation; two continued on probation; and none was removed from the list.

Last year CPT extended the 1983 guidelines for approved schools to include certified degrees in chemistry with options in biochemistry, polymer chemistry, and chemistry education. At a Division of Chemical Education symposium at the ACS national meeting in Dallas members of CPT reviewed the extension of the guidelines and pointed out that more latitude was being given to chemistry departments to develop programs that better meet the needs of the expanding discipline of chemistry. During 1989 the committee approved six programs with an option in biochemistry (1989 total is eight) and two programs in polymer chemistry. The committee is considering other options including materials chemistry and chemical physics.

CPT, in conjunction with the ACS Society Committee on Education and the ACS Committee on Science, is participating in a study by a joint Task Force on Research & Teaching. Within the context of balance between teaching and research, the task force is to identify problems in chemistry education, propose possible solutions, and recommend methods of implementation. A final report is expected to be presented at the ACS national meeting in Boston in April 1990.

In its ongoing effort to serve undergraduate students, and their faculty advisers, in choosing graduate schools appropriate to their particular interests and talents, CPT published the 1989 ACS Directory of Graduate Research. The committee is also developing a concordance of research interests for the directory. In addition, it initiated a revision of the Planning for Graduate Work in Chemistry brochure. This publication offers suggestions for students on how to prepare for graduate study, select a graduate school, apply for admission, and find financial support.

Other CPT activities in 1989 included publication of the papers presented at the symposium celebrating the 50th anniversary of CPT, review of the report of the conference on ACS Policies and Professionalism, publication of an extension of the guidelines, participation in the Committee on Professional Relations Task Force on Academic Guidelines, initiation of a study of the introductory component of the chemistry curriculum, consideration of a study of the content and organization of undergraduate laboratories, participation in the development of the ACS Education Policies for National Survival, and providing input to the ACS Publications Division and the Society Committee on Publications on a proposal for a publication on graduate programs in chemistry.

The committee would like to acknowledge and thank the following visiting associates of the committee who conducted on-site visits to schools on the approved list or applying for ACS approval during 1989: Ivan Bernal, University of Houston; John P. Chesick, Haverford College; Donald J. Darensbourg, Texas A&M University; Luther Erickson, Grinnell College; John P. Idoux, Lamar University; Paul J. Kropp, University of North Carolina, Chapel Hill; Martin J. O'Donnell, Indiana University-Purdue University; Riley O. Schaeffer, University of New Mexico; Barbara R. Shaw, Duke University. ◻

Committee members, 1989

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American Chemical Society

Graduate student enrollments in departments whose undergraduate chemistry programs are ACS approved

	Number of departments	First-year graduate students		All graduate students	
		Full-time	Part-time	Full-time	Part-time
M.S. DEPARTMENTS[a]					
Fall 1984	131	468	270	1099	990
Fall 1985	129	417	292	1106	962
Fall 1986	128	474	264	1190	1051
Fall 1987	127	406	315	1136	993
Fall 1988	127	420	218	998	855
Ph.D. DEPARTMENTS					
Fall 1984	186	3404	227	14,194	1314
Fall 1985	187	3455	208	14,379	1372
Fall 1986	187	3475	235	14,438	1355
Fall 1987	192	3441	201	15,212	1231
Fall 1988	189	3345	171	15,255	1111

[a] Departments whose highest offering is the master's degree in chemistry.

Chemistry and chemical engineering degrees awarded by schools offering an ACS-approved program, 1988–89

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	4	1	3	—			
Adelphi U	0	3	2	—			
Agnes Scott C	3	0	—	—			
Akron, U of	27	2	1	12	a		
Alabama, U of							
Birmingham	1	3	4	4			
Huntsville	2	4	2	—	a		
Tuscaloosa	3	2	2	9	20	3	1
Alaska, U of	4	4	1	—			
Albion C	4	7	—	—			
Albright C	5	13	—	—			
Alfred U	1	0	—	—			
Allegheny C	0	19	—	—			
Alma C	1	4	—	—			
American U	3	0	8	4			
Amherst C	2	9	—	—			
Andrews U	9	2	—	—			
Appalachian State U	3	3	2	—			
Arizona State U	15	11	3	13	a		
Arizona, U of	7	5	6	26	a		
Arkansas State U	0	13	2	—			
Arkansas, U of							
Fayetteville	2	3	2	4			
Little Rock	5	6	1	—	25	10	2
Ashland U	0	4	—	—			
Auburn U	3	16	8	6	24	8	5
Augsburg C	3	5	—	—			
Augustana C							
Illinois	2	4	—	—			
South Dakota	1	4	—	—			
Austin C	0	5	—	—			
Baldwin-Wallace C	1	9	—	—			
Ball State U	8	6	5	—			
Barnard C	2	6	—	—			
Bates C	1	10	—	—			
Baylor U	1	10	0	4			
Beloit C	2	16	—	—			
Bemidji State U	5	9	—	—			
Birmingham-Southern C	3	7	—	—			
Bloomsburg U	1	4	—	—			
Boston C	13	0	1	3			
Boston U	6	10	3	7			
Bowdoin C	1	32	—	—			
Bowling Green State U	6	20	13	0			
Bradley U	1	9	0	—			
Brandeis U	0	7	5	5			
Bridgeport, U of	3	1	4	—			
Bridgewater State C	0	8	2	—			
Brigham Young U	22	15	2	5	17	9	7
Brown U	0	21	2	17	a		
Bryn Mawr C	13	0	0	1			
Bucknell U	9	14	6	—	17	3	—
Butler U	2	5	4	—			
California Institute of Tech	13	0	9	34	6	4	11
California Polytechnic State U	4	16	2	—			
California State Poly U	11	8	4	—	a		
California State U							
Bakersfield	6	7	—	—			
Chico	0	17	—	—			
Dominguez Hills	2	3	—	—			
Fresno	5	4	5	—			
Fullerton	0	15	7	—			
Hayward	8	14	3	—			
Long Beach	14	26	8	—	a		
Los Angeles	6	16	4	—			
Northridge	13	11	3	—			
Sacramento	12	6	4	—			
San Bernardino	4	2	—	—			
Stanislaus	1	0	—	—			
California, U of							
Berkeley	20	45	13	65	54	12	21
Davis	39	10	2	24	27	5	5
Irvine	14	34	6	19			
Los Angeles	9	73	11	37	a		
Riverside	12	1	10	7			
San Diego	55	0	27	19	a		
Santa Barbara	23	0	11	9	18	6	2
Santa Cruz	20	0	1	1			
Calvin C	2	16	—	—			
Canisius C	7	8	—	—			
Capital U	0	4	—	—			
Carleton C	3	14	—	—			
Carnegie Mellon U	16	0	5	8	40	11	16
Carroll C	0	8	—	—			
Carthage C	3	0	—	—			
Case Western Reserve U	4	33	7	14	24	9	10
Catholic U of America	0	0	3	1			
Centenary C of Louisiana	0	2	—	—			
Central C	0	5	—	—			
Central Connecticut State U	5	1	1				
Central Florida, U of	13	0	5	—			
Central Michigan U	5	13	4	—			
Central State U							
Ohio	0	1	—	—			
Oklahoma	3	6	—	—			
Centre C	0	5	—	—			
Charleston, C of	6	7	—	—			
Chatham C	3	1	—	—			
Chestnut Hill C	6	0	—	—			
Christian Brothers C[b]					a		
Chicago, U of	13	21	15	21			
Cincinnati, U of	23	0	18	24	45	4	3
Citadel, The	5	2	—	—			
City U of New York							
Graduate Center	—	—	0	13			
Brooklyn C	2	15	2	—			
City C	2	6	6	—	a		
Herbert H. Lehman C	3	3	—	—			
Hunter C	3	10	—	—			
Queens C	1	8	3	—			
Clarion U	3	0	—	—			
Clark U	6	9	2	1			
Clarkson U	6	5	6	3	66	11	5
Clemson U	5	2	—	—	18	8	1
Cleveland State U	9	4	2	1	11	4	2
Coe C	1	3	—	—			
Colby C	2	7	—	—			
Colgate U	11	2	—	—			
Colorado C	5	2	—	—			
Colorado School of Mines	7	0	6	1	56	13	3
Colorado State U	12	17	4	10	a		
Colorado, U of							
Boulder	1	33	4	22	26	8	7
Colorado Springs	8	3	—	—			
Denver	6	5	4	—			
Columbia U	11	5	27	25	27	20	6
Concordia C	2	7	—	—			
Connecticut C	3	3	—	—			
Connecticut, U of	8	13	10	10	14	8	2
Cooper Union[b]					a		
Cornell C	0	6	—	—			
Cornell U	22	18	32	37	26	2	10
Creighton U	7	16	0	—			
Dartmouth C	0	11	1	2			
David Lipscomb U	2	9	—	—			
Davidson C	5	8	—	—			
Dayton, U of	13	7	—	—	16	9	—
De Paul U	0	2	13	—			
DePauw U	1	14	—	—			
Delaware State C	3	0	1	—			
Delaware Valley C of Science & Agriculture	5	0	—	—			
Delaware, U of	29	11	7	18	38	1	16
Delta State U	1	8	—	—			
Denison U	0	6	—	—			
Denver, U of	2	2	5	3			
Detroit, U of	3	2	6	2	a		
Dickinson C	1	11	—	—			
Drake U	4	0	—	—			
Drew U	4	6	—	—			
Drexel U	5	0	10	3	50	6	2
Duke U	20	27	7	10			
Duquesne U	4	6	8	2			
Earlham C	0	8	—	—			
East Carolina U	6	2	4	—			
East Stroudsburg U	1	6	0	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
East Tennessee State U	6	4	4	—			
East Texas State U	1	7	1	—			
Eastern Illinois U	7	2	0	—			
Eastern Kentucky U	1	14	1	—			
Eastern Michigan U	5	38	6	—			
Eastern New Mexico U	2	2	0	—			
Eckerd C	2	2	—	—			
Elizabethtown C	3	8	—	—			
Elmhurst C	0	15	—	—			
Emory U	1	26	4	16			
Emporia State U	1	3	2	—			
Evansville, U of	0	3	—	—			
Fairfield U	7	0	—	—			
Fairleigh Dickinson U							
Madison	6	0	5	—			
Teaneck	4	2	4	—			
Fisk U	6	0	1	—			
Florida A&M U	0	3	—	—			
Florida Atlantic U	3	13	1	—			
Florida Institute of Tech	2	3	3	—	7	2	—
Florida International U	7	7	0	—			
Florida State U	2	28	4	9			
Florida, U of	6	48	7	31	31	6	6
Fordham U	0	11	3	—			
Fort Lewis C	2	7	—	—			
Framingham State C	1	0	—	—			
Franklin & Marshall C	10	1	—	—			
Furman U	10	5	8	—			
Geneva C	2	5	—	—			
George Mason U	7	0	0	—			
George Washington U	1	7	0	1			
Georgetown U	14	0	4	7			
Georgia Institute of Tech	20	0	10	13	65	18	10
Georgia State U	6	5	5	—			
Georgia, U of	2	10	8	7			
Gettysburg C	5	1	—	—			
Glassboro State C	10	4	—	—			
Gonzaga U	1	3	—	—			
Goucher C	0	5	—	—			
Grand Valley State U	0	10	—	—			
Grinnell C	10	7	—	—			
Gustavus Adolphus C	6	7	—	—			
Hamilton C	0	1	—	—			
Hamline U	4	3	—	—			
Hampden-Sydney C	4	2	—	—			
Hampton U	6	1	3	—			
Hartford, U of	2	2	0	—			
Hartwick C	4	5	—	—			
Harvard U	26	0	30	19			
Harvey Mudd C	14	0	—	—			
Haverford C	8	0	—	—			
Hawaii, U of	8	3	5	10			
Hendrix C	2	8	—	—			
Hiram C	3	5	—	—			
Hobart & William Smith C	0	9	—	—			
Hofstra U	1	6	—	—			
Hollins C	0	1	—	—			
Holy Cross, C of the	15	8	—	—			
Hope C	13	8	—	—			
Houston, U	10	0	7	10	a		
Howard U	0	20	5	5	11	4	—
Humboldt State U	0	5	—	—			
Idaho State U	2	4	1	—			
Idaho, U of	3	8	5	3	11	11	3
Illinois Benedictine C	16	0	—	—			
Illinois Institute of Tech	6	0	3	2	28	12	3
Illinois State U	29	2	7	—			
Illinois Wesleyan U	2	0	—	—			
Illinois, U of							
Chicago	15	24	10	12	14	4	4
Urbana-Champaign	52	61	17	33	70	15	13
Indiana State U	8	0	2	—			
Indiana U	23	114	9	26			
Indiana U Northwest	1	2	—	—			
Indiana U, South Bend	5	2	—	—			
Indiana U of Pennsylvania	13	7	3	—			
Indiana U-Purdue U							
Fort Wayne	2	1	—	—			
Indianapolis	0	20	8	—			
Interamerican U of Puerto Rico	1	6	—	—			
Iowa State U	8	5	7	22	40	4	5
Iowa, U of	19	2	12	12	22	2	4
Ithaca C	9	0	—	—			
Jackson State U	3	4	3	—			
James Madison U	6	4	—	—			
John Carroll C	9	17	1	—			
Johns Hopkins U	9	5	10	10	12	4	5
Juniata C	6	8	—	—			
Kalamazoo C	6	8	—	—			
Kansas State U	3	3	2	11	11	6	3
Kansas, U of	9	29	5	3	17	4	2
Kean C of New Jersey	3	4	—	—			
Kearney State C	1	7	—	—			
Kennesaw C	0	3	—	—			
Kent State U	12	5	3	1			
Kentucky, U of	8	9	5	4	26	10	2
Kenyon C	8	14	—	—			
King's C	8	2	—	—			
Knox C	0	16	—	—			
La Salle U	4	3	—	—			
Lafayette C	5	7	—	—	12	—	—
Lake Forest C	5	5	—	—			
Lamar U	4	6	5	—	22	4	1
Lawrence Technological U	9	0	—	—			
Lawrence U[c]	6	3	8	4			
Le Moyne C	3	0	—	—			
Lebanon Valley C	6	1	—	—			
Lehigh U	8	2	16	9	36	9	11
Lewis & Clark C	2	3	—	—			
Lincoln U	2	7	—	—			
Long Island U							
Brooklyn Center	1	0	7	—			
C. W. Post C	0	1	—	—			
Loras C	1	3	—	—			
Louisiana State U							
Baton Rouge	5	2	3	18	21	18	5
Shreveport	7	0	—	—			
Louisiana Technological U	2	2	1	—	14	1	1
Louisville, U of	6	14	0	2	19	7	4
Lowell, U of	3	0	5	14	10	5	—
Loyola C in Maryland	2	0	—	—			
Loyola Marymount U	5	1	—	—			
Loyola U							
Chicago	10	6	2	5			
New Orleans	2	4	—	—			
Luther C	0	4	—	—			
Macalester C	1	9	—	—			
Maine, U of	2	3	4	3	25	6	2
Manhattan C[d]	13	6	—	—	8	16	—
Manhattanville C	2	1	—	—			
Mankato State U	4	10	1	—			
Marietta C	2	2	—	—			
Marist C	4	0	—	—			
Marquette U	9	0	4	4			
Marshall U	2	22	1	—			
Maryland, U of							
Baltimore County	9	16	2	1	a		
College Park	8	39	15	16	a		
Massachusetts Institute of Tech	26	0	1	43	45	37	29
Massachusetts, U of	18	9	17	25	24	5	17
McNeese State U	3	3	2	—			
Memphis State U	1	3	3	2			
Mercer U	0	8	—	—			
Merrimack C	1	3	—	—			
Metropolitan State C	13	18	—	—			
Miami U	14	27	5	6			
Miami, U of	3	28	4	4			
Michigan State U	19	9	2	22	41	14	5
Michigan Technological U	11	0	4	1	42	9	—
Michigan, U of							
Ann Arbor	44	0	21	19	50	15	16
Dearborn	16	11	—	—			
Flint	4	3	—	—			
Middle Tennessee State U	0	18	4	—			
Middlebury C	2	17	—	—			
Midwestern State U	2	2	—	—			
Millersville U	0	13	—	—			
Millsaps C	2	20	—	—			
Minnesota, U of							
Minneapolis	32	0	10	29	a		
Duluth	11	12	4	—			
Mississippi C	1	4	—	—			
Mississippi State U	1	10	5	2	a		

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Mississippi, U of	3	12	1	1	5	3	2
Missouri Western State C	7	0	—	—			
Missouri, U of							
Columbia	14	7	11	3	a		
Kansas City	3	11	0	2			
Rolla	7	0	3	6	61	13	1
St. Louis	7	8	5	4			
Monmouth C	2	0	—	—			
Montana C of Mineral Science & Technology	4	1	3	—			
Montana State U	8	6	0	7	22	8	1
Montana, U of	5	4	1	0			
Montclair State C	2	10	3	—			
Moorhead State U	3	0	—	—			
Moravian C	2	7	—	—			
Morehouse C[c]	2	0	6	0			
Morgan State U	2	4	—	—			
Mount Holyoke C	0	7	3	0			
Mount Saint Vincent, C of[d]	0	0	—	—			
Muhlenberg C	0	13	—	—			
Murray State U	5	8	6	—			
Muskingum C	1	7	—	—			
Nebraska, U of							
Lincoln	3	9	9	20	a		
Omaha	8	3	—	—			
Nebraska Wesleyan U	1	4	—	—			
Nevada, U of							
Las Vegas	5	3	0	—			
Reno	0	5	3	2			
New Hampshire, U of	7	5	6	3	a		
New Jersey Institute of Tech[b]					a		
New Mexico Highlands U	0	0	0	—			
New Mexico Institute of Mining & Tech	5	0	6	1			
New Mexico State U	0	22	7	3	12	8	1
New Mexico, U of	10	6	9	8	10	8	1
New Orleans, U of	0	10	2	1			
New York U	1	56	13	6			
Niagara U	1	9	—	—			
North Alabama, U of	6	11	—	—			
North Carolina A&T State U	6	0	2	—			
North Carolina Central U	2	5	4	—			
North Carolina State U	41	21	5	5	77	5	7
North Carolina, U of							
Asheville	3	2	—	—			
Chapel Hill	26	51	8	17			
Charlotte	1	9	2	—			
Greensboro	9	7	8	—			
Wilmington	4	4	—	—			
North Dakota State U	2	13	4	9			
North Dakota, U of	6	6	2	4	15	1	—
North Texas, U of	3	3	9	7			
Northeast Louisiana U	2	1	3	—			
Northeast Missouri State U	9	5	—	—			
Northeastern Illinois U	2	12	6	—			
Northeastern U	0	9	5	12	a		
Northern Arizona U	6	23	2	—			
Northern Colorado, U of	4	2	0	0			
Northern Illinois U	11	15	5	4			
Northern Iowa, U of	4	17	0	—			
Northern Kentucky U	1	2	—	—			
Northern Michigan U	0	3	0	—			
Northwest Missouri State U	1	6	—	—			
Northwestern State U	0	0	—	—			
Northwestern U	7	9	41	18	15	2	12
Notre Dame, U of	2	12	2	11	26	9	11
Oakland U	2	9	2	—			
Oberlin C	10	11	—	—			
Occidental C	4	17	—	—			
Ohio Northern U	1	0	—	—			
Ohio State U	34	0	24	28	39	16	14
Ohio U	10	9	1	3	12	7	2
Ohio Wesleyan U	2	4	—	—			
Oklahoma State U	4	1	3	4	23	14	8
Oklahoma, U of	10	16	9	11	a		
Old Dominion U	7	6	5	—			
Oregon State U	10	0	4	6	29	16	4
Oregon, U of	2	19	8	10			
Pace U							
New York	2	2	—	—			
Pleasantville	3	3	—	—			
Pacific Lutheran U	3	9	—	—			
Pacific, U of the	0	9	0	0			
Pennsylvania State U	9	25	9	36	92	21	6
Pennsylvania, U of	3	15	3	22	14	11	7
Philadelphia C of Pharmacy & Science	2	1	1	1			
Philadelphia C of Textiles & Science	2	0	—	—			
Pittsburgh State U	3	3	3	—			
Pittsburgh, U of	13	65	6	22	44	11	8
Polytechnic U	2	0	10	11	15	11	6
Pomona C	2	4	—	—			
Portland State U	1	9	3	3			
Portland, U of	2	0	—	—			
Pratt Institute[b]					a		
Princeton U	10	7	19	17	14	0	15
Providence C	2	3	0	0			
Puerto Rico, U of							
Mayaguez	2	7	6	—	43	7	—
Rio Piedras	4	31	4	4			
Puget Sound, U of	3	3	—	—			
Purdue U	19	23	13	49	92	14	14
Purdue U Calumet	1	0	—	—			
Ramapo C of New Jersey	3	2	—	—			
Randolph Macon C	1	2	—	—			
Randolph-Macon Woman's C	0	2	—	—			
Redlands, U of	0	3	—	—			
Reed C	5	4	—	—			
Rensselaer Polytechnic Inst	18	0	13	12	37	7	10
Rhode Island C	7	5	—	—			
Rhode Island, U of	2	1	6	2	14	3	3
Rhodes C	1	8	—	—			
Rice U	1	5	16	14	14	5	6
Richmond, U of	5	9	—	—			
Rider C	2	0	—	—			
Ripon C	5	2	—	—			
Roanoke C	3	3	—	—			
Rochester Institute of Tech	5	22	6	—			
Rochester, U of	2	7	20	21	17	13	9
Rockhurst C	2	3	—	—			
Rollins C	1	0	—	—			
Roosevelt U	5	1	4	—			
Rose-Hulman Institute of Tech	11	0	—	—	25	2	—
Russell Sage C	2	4	—	—			
Rutgers U							
Camden C	2	1	—	—			
New Brunswick	5	34	5	17	26	10	9
Newark C of Arts & Sciences	10	7	6	6			
Saginaw Valley State U	3	9	—	—			
St. Anselm C	2	1	—	—			
St. Catherine, C of	0	7	—	—			
St. Cloud State U	9	5	—	—			
St. John Fisher C	3	0	—	—			
St. John's U/C of St. Benedict	4	4	—	—			
St. John's U	4	.0	2	—			
St. Joseph C	3	0	7	—			
St. Joseph's U	11	8	7	—			
St. Lawrence U	2	4	—	—			
St. Louis U	7	8	3	—			
St. Mary's C	0	11	—	—			
St. Michael's C	0	0	—	—			
St. Olaf C	1	47	—	—			
St. Peter's C	2	0	—	—			
St. Thomas, C of	1	10	—	—			
Salem State C	1	0	—	—			
Sam Houston State U	2	3	3	—			
San Diego State U	27	0	15	1			
San Francisco State U	5	23	5	—			
San Francisco, U of	2	2	0	—			
San Jose State U	26	7	6	—	a		
Sangamon State U	3	0	—	—			
Santa Clara U	2	10	—	—			
Scranton, U of	5	15	11	—			
Seattle U	1	6	—	—			
Seton Hall U	6	10	11	2			
Shippensburg U	8	5	1	—			
Siena C	6	0	—	—			
Simmons C	0	1	—	—			
Skidmore C	0	12	—	—			
Smith C	2	3	0	0			
Sonoma State U	1	14	—	—			
South Alabama, U of[b]					10	0	—
South Carolina, U of	3	16	6	14	14	4	0

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
South Dakota School of Mines & Tech	6	2	1	—	19	4	—
South Dakota State U	0	29	4	—			
South Dakota, U of	5	12	2	—			
South Florida, U of	18	24	2	3	15	9	1
Southeast Missouri State U	2	6	—	—			
Southeastern Louisiana U	0	0	—	—			
Southeastern Massachusetts U	8	6	6	—			
Southern California, U of	9	4	1	22	10	8	2
Southern Colorado U	1	9	0	—			
Southern Illinois U							
Carbondale	4	6	7	8			
Edwardsville	11	2	4	—			
Southern Methodist U	4	2	0	—			
Southern Mississippi, U of	0	19	1	4			
Southern Oregon State C	6	6	—	—			
Southern U and A&M C	3	6	2	—			
Southwest Missouri State U	6	13	—	—			
Southwest State U	5	2	—	—			
Southwest Texas State U	17	2	4	—			
Southwestern Louisiana, U of	1	11	2	—	15	4	—
Southwestern Oklahoma State U	1	3	—	—			
Stanford U	8	2	6	21	6	9	11
State U of New York							
Albany	13	2	3	4			
Binghamton	7	15	13	6			
Buffalo	14	10	8	15	46	9	12
Stony Brook	13	15	9	19			
C at Brockport	1	5	—	—			
C at Buffalo	4	7	4	—			
C at Cortland	1	4	—	—			
C at Fredonia	6	2	0	—			
C at Geneseo	3	2	—	—			
C at New Paltz	2	2	1	—			
C at Oneonta	0	17	0	—			
C at Oswego	6	4	5	—			
C at Plattsburgh	11	5	3	—			
C at Potsdam	0	14	—	—			
C at Purchase	2	5	—	—			
Stephen F. Austin State U	5	0	1	—			
Stetson U	2	4	—	—			
Stevens Institute of Tech	3	3	7	3	7	10	5
Stockton State C	1	9	—	—			
Suffolk U	0	2	—	—			
Susquehanna U	0	2	—	—			
Swarthmore C	4	4	—	—			
Syracuse U	7	8	2	11	12	9	7
Temple U	12	0	3	5			
Tennessee Technological U	2	6	3	—	18	1	1
Tennessee, U of							
Chattanooga	10	13	—	—			
Knoxville	3	11	6	7	33	12	2
Martin	0	9	—	—			
Texas A&I U	8	1	1	—	10	5	—
Texas A&M U	11	10	9	34	50	16	16
Texas Christian U	1	17	3	1			
Texas Southern U	3	0	4	—			
Texas Tech U	11	10	4	7	a		
Texas Woman's U	2	1	3	0			
Texas, U of							
Arlington	9	7	1	13			
Austin	53	0	6	32	66	9	12
Dallas	3	0	2	2			
El Paso	3	0	9	—			
Thiel C	0	2	—	—			
Thomas More C	2	0	—	—			
Toledo, U of	4	9	5	2	19	11	2
Towson State U	1	6	—	—			
Trenton State C	7	0	—	—			
Tri-State U[b]					a		
Trinity C	15	1	0	—			
Trinity U	6	17	—	—			
Tufts U	0	6	1	4	15	11	—
Tulane U of Louisiana	0	6	0	2	6	3	2
Tulsa, U of	4	0	—	—	17	5	1
Tuskegee Institute	0	1	1	—	4	—	—
Union C	2	14	—	—			
U. S. Air Force Academy	9	4	—	—			
U. S. Naval Academy	17	0	—	—			
Ursinus C	3	10	—	—			
Utah State U	11	0	5	3			
Utah, U of	4	19	6	10	a		
Valparaiso U	1	15	—	—			
Vanderbilt U	1	9	6	5	16	3	2
Vassar C	2	3	3	—			
Vermont, U of	8	0	3	7			
Villanova U	8	0	14	2	17	9	—
Virginia Commonwealth U	8	8	1	4			
Virginia Military Institute	8	0	—	—			
Virginia Polytechnic Institute & State U	21	12	8	18	38	6	8
Virginia, U of	6	77	11	22	21	12	6
Wabash C	4	13	—	—			
Wagner C	4	4	—	—			
Wake Forest U	14	11	2	0			
Washburn U	3	3	—	—			
Washington C	0	0	—	—			
Washington State U	6	8	3	3	17	7	1
Washington U	5	4	15	9	21	6	6
Washington, U of	33	19	20	22	a		
Washington & Jefferson C	3	23	—	—			
Washington & Lee U	0	11	—	—			
Wayne State U	15	35	10	22	41	13	3
Waynesburg C	1	2	—	—			
Weber State C	6	2	—	—			
Wellesley C	8	23	—	—			
Wesleyan U	0	8	1	8			
West Chester U	3	18	2	—			
West Florida, U of	2	2	—	—			
West Texas State U	1	7	0	—			
West Virginia Institute of Tech[b]					12	1	—
West Virginia State C	5	9	—	—			
West Virginia U	13	38	5	5	16	6	3
Western Illinois U	1	6	7	—			
Western Kentucky U	1	21	2	—			
Western Maryland C	0	2	—	—			
Western Michigan U	1	8	1	1			
Western New England C	0	0	—	—			
Western Washington U	13	15	1	—			
Westminster C	0	1	—	—			
Wheaton C							
Illinois	9	10	—	—			
Massachusetts	3	0	—	—			
Wheeling Jesuit C	0	2	—	—			
Whitman C	2	2	—	—			
Whittier C	0	7	—	—			
Wichita State U	4	10	4	0			
Widener U	2	1	—	—	5	0	—
Wilkes C	3	0	—	—			
Willamette U	2	7	—	—			
William Paterson C of N.J.	0	6	—	—			
William and Mary, C of	13	8	7	—			
Williams C	3	20	—	—			
Winona State U	5	1	—	—			
Wisconsin, U of							
Eau Claire	5	8	—	—			
Green Bay	1	11	—	—			
LaCrosse	3	19	—	—			
Madison	42	3	12	38	24	15	2
Milwaukee	2	13	4	6			
Oshkosh	4	4	—	—			
Parkside	4	9	—	—			
Platteville	0	2	—	—			
River Falls	8	4	—	—			
Stevens Point	12	8	—	—			
Superior	3	2	—	—			
Wittenberg U	2	7	—	—			
Wooster, C of	10	14	—	—			
Worcester Polytechnic Institute	3	8	0	1	a		
Wright State U	14	10	10	—			
Wyoming, U of	6	0	1	4	6	4	0
Xavier U	2	5	—	—			
Xavier U of Louisiana	1	30	—	—			
Yale U	0	15	32	20	1	8	3
Youngstown State U	8	54	5	—	a		
TOTALS	3382	4740	1703	1967	2821	876	553

Note: For brevity, "B.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column. a Data not submitted. b Listed on basis of accreditation by AIChE-ABET. c Master's and Ph.D. degrees given by the Institute of Paper Chemistry. d The chemistry programs at Mount Saint Vincent and Manhattan College are integrated into a combined department with all instruction in chemistry located at Manhattan College e Master's and Ph.D. degrees given by Clark Atlanta University.

Berkeley, Indiana top producers of chemists

For the fifth year in a row the University of California, Berkeley, has graduated more Ph.D. chemists, 65, than any other school in the country and Indiana University has produced the most bachelor's degree chemists, 137.

These are two of the highlights contained in the data in the latest annual report of ACS's Committee on Professional Training (see page 29). As usual, the report, which covers the 1988-89 academic year, tabulates the number of doctoral, master's, and bachelor's degree graduates for all departments with a bachelor's degree program approved by the committee.

Berkeley has topped the list of Ph.D. producers for eight of the past 16 years. For the other eight years the honor went to the University of Illinois, Urbana-Champaign. For 1988-89 Illinois slipped from second place the previous year to ninth with 33 doctoral graduates while Purdue moved up from eighth to second with 49. Massachusetts Institute of Technology took the third spot with 43, moving up from fifth the previous year.

Illinois held on to second place in the ranking of new bachelor's degree chemists with 113. The University of Virginia moved up from sixth to take third place with 83.

The biggest changes came in the rankings for bachelor's degrees certified by ACS. Such graduates are immediately eligible for membership of ACS. Berkeley fell from the top of the list for 1987-88 with 67 graduates to 25th with 20. University of California, San Diego, moved up from 11th to first with 55 such graduates.

Northwestern University moved up from fourth to top the list of master's degrees with 41. Cornell moved up from third to second with 32.

Illinois, the University of Washington, and UC Berkeley were the only three schools to rank in the first 25 for all categories—bachelor's graduates, ACS-certified bachelor's graduates, master graduates, and Ph.D.s.

Michael Heylin

These schools had the most chemistry graduates, 1988–89

Total bachelor graduates		
1.	Indiana U	137
2.	U of Illinois, Urbana-Champaign	113
3.	U of Virginia	83
4.	U of California, Los Angeles	82
5.	U of Pittsburgh	78
6.	U of North Carolina, Chapel Hill	77
7.	U of California, Berkeley	65
8.	Youngstown State U	63
9	North Carolina State U	62
10.	New York U	57
11.	U of California, San Diego	55
12.	U of Florida	54
13.	of Texas, Austin	53
14.	U of Washington	52
15.	West Virginia U	51
16.	Wayne State U	50
17.	U of California, Davis	49
18.	U of California, Irvine	48
18.	St. Olaf C	48
20.	Duke U	47
20.	U of Maryland, College Park	47
22.	U of Wisconsin, Madison	45
23.	U of Michigan, Ann Arbor	44
24.	Eastern Michigan U	43
25.	Purdue U	42
25.	U of South Florida	42

Certified bachelor graduates		
1.	U of California, San Diego	55
2.	U of Texas, Austin	53
3.	U of Illinois, Urbana-Champaign	52
4.	U of Michigan, Ann Arbor	44
5.	U of Wisconsin, Madison	42
6.	North Carolina State U	41
7.	U of California, Davis	39
8.	Ohio State U	34
9.	U of Washington	33
10.	U of Minnesota, Minneapolis	32
11.	U of Delaware	29
11.	Illinois State U	29
13.	U of Akron	27
13.	San Diego State U	27
15.	Harvard U	26
15.	Massachusetts Inst of Tech	26
15.	U of North Carolina, Chapel Hill	26
15.	San Jose State U	26
19.	U of California, Santa Barbara	23
19.	U of Cincinnati	23
19.	Indiana U	23
22.	Brigham Young U	22
22.	Cornell U	22
24.	Virginia Polytech Inst & State U	21
25.	U of California, Berkeley	20
25.	U of California, Santa Cruz	20
25.	Duke U	20
25.	Georgia Institute of Tech	20

Master graduates		
1.	Northwestern U	41
2.	Cornell U	32
2.	Yale U	32
4.	Harvard U	30
5.	U of California, San Diego	27
5.	Columbia U	27
7.	Ohio State U	24
8.	U of Michigan, Ann Arbor	21
9.	U of Rochester	20
9.	U of Washington	20
11.	Princeton U	19
12.	U of Cincinnati	18
13.	U of Illinois, Urbana-Champaign	17
13.	U of Massachusetts	17
15.	Lehigh U	16
15.	Rice U	16
17.	U of Chicago	15
17.	U of Maryland, College Park	15
17.	San Diego State U	15
17.	Washington U	15
21.	Villanova U	14
22.	Bowling Green State U	13
22.	U of California, Berkeley	13
22.	De Paul U	13
22.	New York U	13
22.	Purdue U	13
22.	Rensselaer Polytech Inst	13
22.	State U of New York, Binghamton	13

Doctoral graduates		
1.	U of California, Berkeley	65
2.	Purdue U	49
3.	Massachusetts Inst of Tech	43
4.	U of Wisconsin, Madison	38
5.	U of California, Los Angeles	37
5.	Cornell U	37
7.	Pennsylvania State U	36
8.	Texas A&M U	34
9.	U of Illinois, Urbana-Champaign	33
10.	U of Texas, Austin	32
11.	U of Florida	31
12.	U of Minnesota, Minneapolis	29
13.	Ohio State U	28
14.	U of Arizona	26
14.	Indiana U	26
16.	Columbia U	25
16.	U of Massachusetts	25
18.	U of California, Davis	24
18.	U of Cincinnati	24
20.	U of Colorado, Boulder	22
20.	Iowa State U	22
20.	Michigan State U	22
20.	U of Pennsylvania	22
20.	U of Pittsburgh	22
20.	U of Southern California	22
20.	U of Virginia	22
20.	U of Washington	22
20.	Wayne State U	22

A1250-1

Top 100 chemical producers
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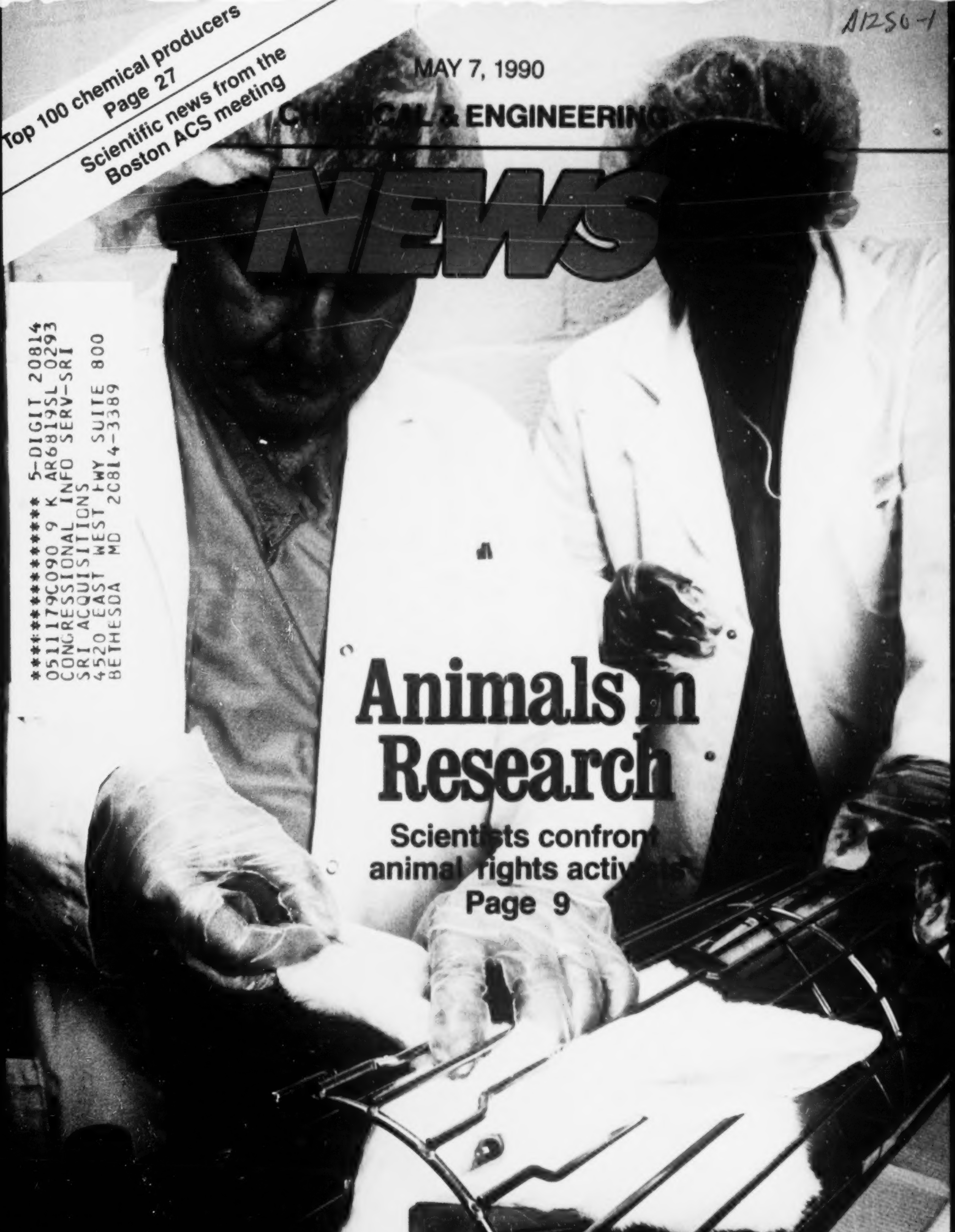
Scientific news from the
Boston ACS meeting

MAY 7, 1990

CHEMICAL & ENGINEERING

NEWS



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Animals in Research

Scientists confront
animal rights activists
Page 9

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CHEMICAL & ENGINEERING
NEWS
MAY 7, 1990

News of the Week

- **Scientific review panel endorses National Toxicology Program's findings on sodium fluoride that suggest equivocal evidence for carcinogenicity in male rats.** Page 4
- **California's environmental initiative, dubbed "Big Green," gets more than enough signatures to place it on November ballot.** Page 5
- **EPA is developing regulations that would further limit dioxin levels in paper products.** Page 5
- **Academic research funding system overburdened and not organizationally equipped for the 1990s, says study by Congressional group.** Page 6
- **Gene-engineered bovine growth hormone becomes first such product banned in U.S.** Page 6

Cover: Photo courtesy of National Institutes of Health

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Business

Combined sales of the 100 largest U.S. chemical producers set another record in 1989, up 6% from the previous year to $181 billion. **Page 27**

Outlook for biotechnology industry is bright, industry leaders told a symposium at the ACS national meeting in Boston. **Page 39**

Government

National recycling program to prevent emission of CFCs into the atmosphere is being proposed by EPA. **Page 44**

U.S. firms are being helped to develop a global environment management initiative by former EPA Administrator Lee M. Thomas. **Page 45**

Science/Technology

From the Boston meeting: Alternate theories of conductivity in nonconjugated polymers debated; GE develops new methods to make resins from cyclic oligomers; *C*-alkylation effective in solubilizing coals; Monsanto uses chiral catalyst to synthesize arthritis drug naproxen; alternatives to thermal cracking of higher hydrocarbons for ethylene probed; new class of synthetic lubricants for extreme service conditions developed. **Page 53**

Books

"The American Synthetic Rubber Research Program" traces U.S. government's World War II efforts to boost rubber production. **Page 64**

ACS News

The national meeting in Boston offered participants a variety of activities, captured on film by C&EN's roving photographer. **Page 66**

News Focus

Biomedical and behavioral researchers are mounting efforts to counter animal rights groups whose antivivisection activities have included criticism of scientists and attacks on labs. Page 9

Chemical & Engineering News
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LETTERS

Apologies to Gerber

SIR: I write to correct a serious mistake I made in my Priestley Medal Address (C&EN, April 23, page 24). I incorrectly identified Gerber as involved in a baby food scandal. The intended reference was to Beech-Nut Nutrition Corp., which distributed as pure apple juice concoctions of sugars with little real apple juice. I sincerely apologize to Gerber for my mistake.

Roald Hoffmann
Professor
Cornell University

Chemical information systems

SIR: In regard to Stuart Kaback's letter (C&EN, Feb. 5, page 2), as a 10-plus year ACS member, I have been involved in chemical information for only six years, and have some thoughts in this area. It is widely believed that the availability of information is important to all sections of the chemical world. As a person whose job it is to provide comprehensive retrieval of a wide variety of chemical information, I know how to use at least seven different computer-based systems as tools. I have learned that each system has strengths and weaknesses. When the same data are available on multiple systems, the experienced searcher realizes that for different questions different systems are best. Often, answering a specific question is only possible using the strengths of one system. No one system is best for all types of questions.

Also, in my six short years in chemical information, I have seen tremendous change in both databases and host systems. This change has produced better databases and better host systems. It is notable that change comes fastest when there is competition of some sort. One database improves its indexing of polymers, then another starts to improve its polymer indexing. One system allows graphical input of chemical structures for searching, then another develops a similar system. The list is endless. This is very good for people who need chemical information. More tools are available to allow them to answer whatever kinds of questions they have.

To the specific point of CAS's licensing policies and income: Any chemical information user's worst nightmare is an insolvent CAS decreasing its level of service, or quitting altogether. We all want CAS to get the money it needs to continue. The fairness of using CAS to produce income to fund other ACS programs is doubtful to many, and certainly should never be a major goal of the program. CAS's purpose is to provide chemical information to the chemical community. Having *CA*'s abstracts and structure data available on as many host systems as possible improves access to this information.

CAS's pricing policies are a separate matter. CAS must be able to charge whatever is needed to keep CAS operational with a high level of performance. However, keeping STN usage high by maintaining such important data exclusively does not provide good service to the information world, nor does it provoke the completion [*sic*] needed to induce improvements needed to keep STN viable in the long term. STN is a very good system. If allowed to stand on its own, people would use it for its flexibility and ability to answer their questions.

If CAS makes its data available as widely as possible, this will only increase its true customer base. I wish CAS long life and success, but I want it to provide chemical information to a wide audience, thus helping the chemical world as a whole.

Jerri J. Chase
Dow Chemical Patent
Department, Midland, Mich.

Training more chemists

SIR: Amidst all the concern about training more chemists I would like to ask, "Why?" I see no shortage of chemists—particularly Ph.D.s. Quite the contrary, I see people leaving science for better career opportunities elsewhere. Shortages, where they occur, result from the very specific experience requirements that today's employers often make.

Do we, then, need to train more chemists to meet the challenges of tomorrow? Perhaps. There certainly are a lot of problems that need to be solved. I hope that someday government and industry will recognize that they must employ more scientists in order to solve these problems. But I wouldn't advise anyone to gamble his or her career on that happening soon. Wouldn't we all be better off if ACS spent more time pro-

Correction

- April 2, page 25: Stuart M. Kaback, not Kabak, was recently promoted at Exxon Research & Engineering Co.

Top 100 Chemical Producers Post Another Record Sales Year

Combined sales of 100 largest firms totaled $181 billion last year, up 6% from 1988; sales fell for 25, however, compared with five in previous year

William J. Storck,
C&EN Northeast News Bureau

Although 1989 was a year in which chemical industry growth slowed, thanks to the first half, it still produced records in the volume of business done by producers of chemical products.

This is reflected in the results for the companies listed in C&EN's annual ranking of the Top 100 chemical producers. However, as in past years, restructuring of the industry has brought changes to the companies listed and in the relative rankings of the producers.

For 1989, sales of chemicals on a dollar basis for the 100 companies rose 6% from sales of the 100 firms ranked for 1988, reaching a total of slightly more than $181 billion. This represents more than 70% of the government's estimates of shipments of chemicals and allied products last year. And, if drugs are excluded as C&EN does for its rankings, the Top 100 companies accounted for almost 85% of U.S. chemical shipments.

However, in spite of the increase in sales for the total group of companies, 25 of the firms recorded sales declines for the year. This is up considerably from the 1988 ranking, when only five had sales declines.

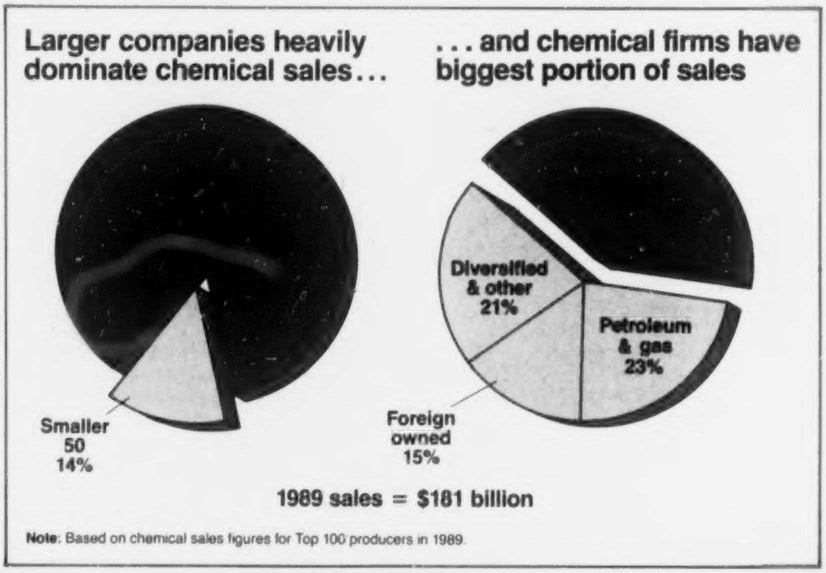
The mix of companies making up the chemical sales figures in 1989 remained fairly constant with the previous year. The 50 largest companies continue to dominate, providing 86% of the total sales dollars. This is the same percentage as in the ranking for 1988.

Firms classified as chemical companies also continue to have the biggest share of the sales total. These firms accounted for 41% of the total in 1989. This was followed by diversified companies with 21% of total sales in 1989, down from 24% in 1988. Petroleum and gas companies contributed 23% of the total, up from 20% for the 1988 ranking. And U.S. subsidiaries of foreign firms had a 15% share, up from 14% in the previous year.

Eight companies are new to the list for 1989, but in most instances they represent companies that were previously on the list and have been spun off, as in the case of Lyondell Petrochemical replacing its former parent, Atlantic Richfield. Or they are U.S. firms that have been acquired, with the new parent now listed—an example is Pennwalt being replaced by Atochem.

Other companies new to the Top 100 include Tenneco, which has made its chemical sales figures easier to obtain. Degussa and Nova Corp. are two foreign-owned firms now divulging U.S. chemical sales. Eagle-Picher and Nu-West, which acquired the former Beker Industries fertilizer operations a few years ago, have had chemical growth sufficient to bring them into the Top 100 producers.

Atlas Powder, the remaining company new to the rankings for 1989, is in reality a company in limbo. It is currently owned by Tyler Corp., now off the list. Because of the pending sale of Atlas to ICI, Tyler is carrying Atlas separately in its annual report. Besides Atlantic Richfield, Pennwalt, and Tyler, the other companies not on the list for 1989 are Eli Lilly, which has assigned its agricultural chemicals to a joint venture with Dow Chemical and no longer reports chemical sales; Himont, now wholly owned by Italy's


Larger companies heavily dominate chemical sales . . .

. . . and chemical firms have biggest portion of sales

1989 sales = $181 billion

Note: Based on chemical sales figures for Top 100 producers in 1989.

Chemical sales, operating profits increased for most producers

Rank 1989	1988	Company	Chemical sales 1989 ($ millions)	Change from 1988	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1988	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$15,249	3.6%	42.9%	Diversified	$2769	6.0%	57.0%	18.2%	$12,514	36.0%	22.1%
2	2	**Dow Chemical**	14,179	4.0	80.6	Basic chemicals	3543	−2.5	88.4	25.0	12,202	55.0	29.0
3	3	**Exxon**	10,559	5.7	11.1	Petroleum	1609	−13.6	19.2	15.2	7,118	8.6	22.6
4	4	**Union Carbide**	7,962[d]	4.7	91.1	Basic chemicals	1225	−20.6	96.5	15.4	6,172	72.2	19.8
5	5	**Monsanto**	5,782	4.5	66.6	Basic chemicals	929	2.1	86.2	16.1	4,482	52.1	20.7
6	6	**Hoechst Celanese**	5,658	5.4	94.0	Basic chemicals	576	2.3	114.7	10.2	na	na	na
7	7	**Occidental Petroleum**	5,203	11.3	25.9	Petroleum	1235	17.6	260.0	23.7	5,508	26.6	22.4
8	12	**General Electric**	4,929[d]	39.3	9.0	Diversified	1057	44.2	15.5	21.4	8,023	6.3	13.2
9	8	**BASF**	4,461	6.0	82.3	Basic chemicals	na	na	na	na	na	na	na
10	9	**Amoco**	4,274	−1.8	17.8	Petroleum	744	−27.2	21.6	17.4	3,158	10.4	23.6
11	10	**Mobil**	4,039	−5.6	7.3	Petroleum	774	−9.0	16.8	19.2	2,702	6.9	28.6
12	11	**Shell Oil**	3,833	−4.3	16.2	Petroleum	941	26.1	37.9	24.5	3,824	13.9	24.6
13	15	**Eastman Kodak**	3,522	16.1	19.1	Photo equipment	643	2.4	40.4	18.3	3,238	13.7	19.9
14	13	**Chevron**	3,328	3.9	10.4	Petroleum	532	−13.6	29.5	16.0	2,476	7.3	21.5
15	14	**W. R. Grace**	3,256	4.0	53.2	Specialty chemicals	406	4.6	66.0	12.5	2,436	43.4	16.7
16	16	**Allied-Signal**	2,993	−1.3	25.1	Diversified	355	−5.8	37.5	11.9	1,879	18.5	18.9
17	17	**Arco Chemical**	2,663	−1.4	100.0	Basic chemicals	580	−19.7	100.0	21.8	2,655	100.0	21.8
18	18	**Rohm & Haas**	2,661	5.0	100.0	Basic chemicals	287	−23.9	100.0	10.8	2,128	86.7	13.5
19	20	**Air Products**[e]	2,481	10.9	93.9	Basic chemicals	425	3.8	109.5	17.1	2,835	84.2	15.0
20	19	**Phillips Petroleum**	2,449	−2.7	19.8	Petroleum	652	−28.4	46.9	26.6	1,377	12.2	47.3
21	23	**Bayer USA**	2,300	7.5	42.4	Diversified chemicals	127[f]	7.6	82.5	5.5	na	na	na
22	22	**American Cyanamid**	2,241	3.4	46.4	Basic chemicals	236	10.0	40.7	10.5	1,779	35.8	13.2
23	24	**Ashland Oil**[e]	2,230	6.7	26.3	Petroleum	98	−3.9	34.8	4.4	744	16.7	13.2
24	21	**Quantum Chemical**	2,015	−9.2	75.4	Basic chemicals	423	−40.5	89.0	21.0	1,830	60.9	23.1
25	25	**B. F. Goodrich**	1,977	−4.7	81.7	Basic chemicals	261	−15.4	95.0	13.2	1,467	64.5	17.8
26	—	**Lyondell Petrochemical**	1,905	0.1	35.6	Petroleum	na	na	na	na	na	na	na
27	28	**Texaco**	1,818	6.3	5.6	Petroleum	399	5.3	11.6	21.9	1,126	4.4	35.4
28	—	**Atochem**	1,778	206.0	100.0	Basic chemicals	na	na	na	na	na	na	na
29	38	**Aluminum Co. of America**	1,700	39.9	15.8	Nonferrous metals	na	na	na	na	2,500	21.7	0
30	27	**Hercules**	1,632	−4.2	52.8	Basic chemicals	126	−0.6	62.5	7.7	1,294	35.4	9.7
31	37	**Akzo**	1,612	19.7	100.0	Basic chemicals	117	54.4	100.0	7.3	na	na	na
32	35	**Rhône-Poulenc**	1,600	14.3	100.0	Specialty chemicals	na	na	na	na	na	na	na
33	32	**Dow Corning**	1,575	6.6	100.0	Specialty chemicals	163[f]	8.2	100.0	10.3	na	na	na
34	34	**National Starch**	1,569	10.9	100.0	Specialty chemicals	226	13.2	100.0	14.4	1,269	100.0	17.8
35	33	**FMC**	1,542	7.4	45.1	Machinery	220	−1.5	55.5	14.3	1,329	47.1	16.6
36	30	**Ethyl**	1,520	−9.2	62.5	Basic chemicals	283	−8.5	69.4	18.6	1,055	18.7	26.8
37	31	**BP America**	1,426	−5.4	6.1	Petroleum	68	−34.6	3.3	4.8	na	na	na
38	36	**Olin**	1,265	−5.9	51.2	Basic chemicals	174	65.7	76.7	13.5	936	49.2	18.6
39	39	**Unocal**	1,276	6.0	11.6	Petroleum	74	−59.3	12.8	5.8	622	6.7	11.9
40	—	**Tenneco**	1,224	0.5	8.7	Petroleum	119	−1.7	8.5	9.7	1,229	7.2	9.7
41	44	**IMC Fertilizer**[e]	1,222	12.5	100.0	Agrochemicals	257	17.7	100.0	21.1	1,678	100.0	15.3
42	40	**Huntsman Chemical**	1,200	0	100.0	Basic chemicals	na	na	na	na	na	na	na
42	43	**Ciba-Geigy**	1,200[h]	9.3	34.3	Specialty chemicals	na	na	na	na	na	na	na
44	42	**PPG Industries**	1,175	5.6	20.5	Glass products	257	0.8	35.2	21.9	1,033	18.3	24.9
45	47	**Lubrizol**	1,124	8.5	92.1	Specialty chemicals	321	4.8	90.2	28.5	733	76.3	43.8
46	41	**Freeport-McMoRan**	1,105	−2.3	95.6	Agrochemicals	108	−45.3	82.1	9.8	876	72.2	12.3
46	46	**Georgia Gulf**	1,105	4.1	100.0	Basic chemicals	300	−3.9	100.0	27.2	473	100.0	63.4
48	51	**Nalco Chemical**	1,071	7.7	100.0	Specialty chemicals	181	14.1	100.0	16.9	939	100.0	19.3
49	49	**NL Industries**	1,001	−0.6	100.0	Basic chemicals	278	6.5	100.0	27.8	na	na	na
50	50	**Solvay America**	1,000[d]	0	100.0	Basic chemicals	na	na	na	na	na	na	na

Rank 1989	1988		Chemical sales 1939 ($ millions)	Change from 1988	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1988	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	45	**Aristech**	$996	−6.5%	100.0%	Basic chemicals	$140	−28.9%	100.0%	14.0%	$721	100.0%	19.4%
52	54	**Cabot[e]**	951	5.2	49.1	Basic chemicals	112	−31.8	176.7	11.7	790	55.7	14.1
53	56	**Terra Chemicals**	949	11.9	100.0	Agrochemicals	na	na	na	na	na	na	na
54	55	**Morton International[g]**	935	7.0	66.5	Diversified	144	−3.0	69.6	15.4	861	63.1	16.8
55	60	**Farmland Industries[i]**	903	17.7	30.3	Agricultural supplies	90	20.3	50.6	10.0	382	32.3	23.6
56	—	**Degussa**	886	na	51.4	Natural gas	na	na	na	na	na	na	na
57	57	**International Flavors**	870	3.6	100.0	Specialty chemicals	223	6.6	100.0	25.7	684	70.6	32.6
58	52	**CF Industries**	856	−10.6	100.0	Agrochemicals	27	−75.1	100.0	3.2	798	100.0	3.4
59	63	**Engelhard**	813	11.9	33.8	Specialty metals	96	−10.3	79.0	11.8	888	66.3	10.8
60	62	**Uniroyal Chemical**	805	9.6	100.0	Specialty chemicals	na	na	na	na	na	na	na
61	68	**Great Lakes Chemical**	792	42.0	100.0	Specialty chemicals	202	40.6	100.0	25.5	1,097	100.0	18.4
62	59	**Vista Chemicals[e]**	779	−0.3	100.0	Basic chemicals	227	16.8	100.0	29.2	567	100.0	40.1
63	—	**Nova**	778	44.3	100.0	Basic chemicals	na	na	na	na	na	na	na
64	61	**Witco**	766[h]	1.0	48.2	Specialty chemicals	18	−71.4	24.2	2.3	377	33.1	4.7
65	65	**H. B. Fuller[j]**	753	10.0	100.0	Specialty chemicals	46	−0.9	100.0	6.1	455	100.0	10.1
66	66	**American Petrofina**	662	−2.9	21.8	Petroleum	138	−50.7	69.4	20.9	435	17.3	31.9
67	53	**International Minerals[g]**	640	−31.3	65.1	Agrochemicals	50	−57.4	37.7	7.8	673	34.1	7.4
68	70	**GAF**	600	10.1	59.4	Specialty chemicals	171	13.9	93.9	28.5	na	na	na
69	71	**Kerr-McGee**	592	14.3	19.2	Petroleum	125	22.5	40.7	21.1	794	23.8	15.7
70	64	**Sterling Chemical[e]**	581	−16.9	100.0	Basic chemicals	156	−49.9	100.0	26.9	329	100.0	47.5
71	—	**Atlas Powder**	543	11.9	100.0	Explosives	na	na	na	na	na	na	na
72	77	**Betz Laboratories**	517	15.4	100.0	Specialty chemicals	88	15.1	100.0	16.9	369	100.0	23.7
73	75	**Sun Co.**	510	10.6	4.6	Petroleum	na	na	na	na	na	na	na
74	72	**Pfizer**	509	−0.6	9.0	Drugs	39	−20.2	4.1	7.7	538	6.5	7.2
75	76	**Hoffmann-La Roche**	500[k]	11.1	22.7	Drugs	na	na	na	na	na	na	na
76	74	**Merck**	492	5.6	7.5	Drugs	59	−3.6	2.7	12.0	470	7.0	12.6
77	78	**Ferro**	478	7.8	44.1	Specialty materials	17	−6.0	18.2	3.6	251	37.5	6.8
78	69	**Borden Chemicals**	466	−15.7	100.0	Dairy products	95	−39.0	99.7	20.4	550	100.0	17.3
79	80	**Loctite[g]**	457	9.5	100.0	Specialty chemicals	80	21.1	100.0	17.5	362	100.0	22.0
80	82	**Lonza**	450	13.9	100.0	Specialty chemicals	na	na	na	na	na	na	na
81	79	**Dexter**	439	3.4	51.7	Rubber products	31	20.5	33.1	7.1	310	44.6	10.1
82	83	**Vulcan Materials**	430	12.5	40.0	Nonmetallic minerals	86	30.7	42.9	20.1	na	na	na
83	81	**Union Camp**	413	3.7	15.0	Diversified	14	−54.8	2.7	3.3	289	8.5	4.7
84	85	**Sigma-Aldrich**	359	18.9	81.4	Specialty chemicals	87	12.8	86.9	24.2	418	88.5	20.7
85	84	**Stepan**	346	4.0	100.0	Specialty chemicals	12	−43.1	100.0	3.4	215	100.0	5.4
86	89	**First Mississippi[g]**	308	29.5	70.9	Agrochemicals	27	16.0	82.3	8.7	166	34.7	16.2
87	90	**Crompton & Knowles**	281	20.9	79.0	Specialty chemicals	36	37.0	71.4	12.9	170	78.2	21.2
88	87	**Chemed**	277	2.7	52.3	Specialty chemicals	38	14.3	67.4	13.8	137	40.7	28.0
89	86	**Petrolite[l]**	275	0.2	94.3	Specialty chemicals	19	−12.3	217.6	6.7	191	79.6	9.7
90	91	**Calgon Carbon**	253	12.1	100.0	Basic chemicals	57	10.8	100.0	22.4	234	100.0	24.3
90	88	**Georgia-Pacific**	253	5.0	2.5	Wood products	na	na	na	na	na	na	na
92	93	**Mississippi Chemical[g]**	209	12.4	100.0	Farm cooperative	47	157.7	100.0	22.5	577	100.0	8.1
93	92	**Sherex**	188	−6.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
94	94	**Quaker Chemical**	182	9.0	100.0	Specialty chemicals	23	32.5	100.0	12.7	109	83.3	21.0
95	95	**LeaRonal[m]**	157	0	100.0	Specialty chemicals	16	15.2	100.0	10.3	88	100.0	18.3
96	—	**Nu-West[e]**	155	176.3	100.0	Agrochemicals	−3	def	def	def	170	100.0	def
97	—	**Eagle-Picher**	152[d]	−21.3	20.9	Diversified	15	−35.1	36.9	9.7	86	17.8	17.3
98	96	**Lawter International**	136	8.1	100.0	Specialty chemicals	23	−17.8	100.0	16.5	134	100.0	16.8
99	99	**Cambrex Corp.**	131	8.9	100.0	Specialty chemicals	7	−48.6	100.0	5.0	129	100.0	5.1
100	98	**Agway**	118[k]	−4.3	3.7	Farm cooperative	na	na	na	na	na	na	na

a Operating income is sales less administrative expenses and cost of sales. b Chemical operating profit as a percentage of chemical sales. c Chemical operating profit as a percentage of identifiable chemical assets. d Chemical sales include significant amounts of nonchemical products. e Fiscal year ended Sept. 30. f Chemical net income. g Fiscal year ended June 30. h Does not include all chemical sales. i Fiscal year ended Aug. 31. j Fiscal year ended Nov. 30. k C&EN estimate. l Fiscal year ended Oct. 31. m Fiscal year ended Feb. 28, 1989.

C&EN's five-way ranking of the Top 100 chemical producers

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1989	1989	1988	1989	1989	1988	1989	1989	1988	1989	1989	1988	1989	1989	1988
Agway	$ 118	100	98	na	—	—	na	—	—	na	—	—	na	—	—
Air Products	2,481	19	20	$ 425	16	19	17.1%	32	35	$ 2,835	11	14	15.0%	49	52
Akzo	1,612	31	37	117	45	58	7.3	66	80	na	—	—	na	—	—
Allied	2,993	18	16	355	20	22	11.9	51	55	1,879	18	18	18.9	34	37
Aluminum Co. of America	1,700	29	38	na	—	18	na	—	4	2,500	14	12	na	—	53
American Cyanamid	2,241	22	22	236	29	34	10.5	55	65	1,779	20	19	13.2	52	60
American Petrofina	662	66	66	138	41	29	20.9	23	2	435	53	57	31.9	8	2
Amoco	4,274	10	9	744	10	6	17.4	31	17	3,158	10	9	23.6	17	10
Arco Chemical	2,663	17	17	580	13	12	21.8	18	11	2,655	13	13	21.8	24	17
Aristech	996	51	45	140	40	38	14.0	43	34	721	42	45	19.4	32	16
Ashland Oil	2,230	23	24	98	48	54	4.4	73	81	744	40	42	13.2	52	61
Atlas Powder	543	71	—	na	—	—	na	—	—	na	—	—	na	—	—
Atochem	1,778	28	—	na	—	—	na	—	—	na	—	—	na	—	—
BASF	4,461	9	8	na	—	—	na	—	—	na	—	—	na	—	—
BP America	1,426	37	31	68	57	—	4.8	72	—	na	—	—	na	—	—
Bayer USA	2,300	21	23	na	—	—	na	—	—	na	—	—	na	—	—
Betz Laboratories	517	72	77	88	52	—	16.9	33	—	369	57	—	23.7	16	—
Borden Chemicals	466	78	69	95	50	49	20.4	24	22	550	48	50	17.3	40	39
CF Industries	856	58	52	27	67	51	3.2	77	59	798	37	33	3.4	72	64
Cabot	951	52	54	112	46	41	11.7	53	36	790	39	47	14.1	50	24
Calgon Carbon	253	90	91	57	59	64	22.4	15	19	234	63	67	24.3	15	20
Cambrex Corp.	131	99	99	7	78	81	5.0	71	61	129	71	—	5.1	69	—
Chemed	277	88	87	38	64	68	13.8	44	57	137	69	72	28.0	11	22
Chevron	3,328	14	13	532	15	15	16.0	37	30	2,476	15	16	21.5	25	14
Ciba-Geigy	1,200	42	43	na	—	—	na	—	—	na	—	—	na	—	—
Crompton & Knowles	281	87	90	36	65	71	12.9	47	60	170	66	71	21.2	26	51
Degussa	886	56	—	na	—	—	na	—	—	na	—	—	na	—	—
Dexter	439	81	79	31	66	72	7.1	67	79	310	60	62	10.1	59	73
Dow Chemical	14,179	2	2	3543	1	1	25.0	10	7	12,202	2	1	29.0	9	11
Dow Corning	1,575	33	32	na	—	—	na	—	—	na	—	—	na	—	—
Du Pont	15,249	1	1	2769	2	2	18.2	29	37	12,514	1	2	22.1	22	21
Eagle-Picher	152	97	—	15	75	—	9.7	60	—	86	74	—	17.3	40	—
Eastman Kodak	3,522	13	15	643	12	14	18.3	28	25	3,238	9	10	19.9	30	35
Engelhard	813	59	63	96	49	52	11.8	52	50	888	34	37	10.8	58	62
Ethyl	1,520	36	30	283	24	26	18.6	27	33	1,055	30	26	26.8	12	19
Exxon	10,559	3	3	1609	3	3	15.2	40	31	7,118	4	5	22.6	20	18
FMC	1,542	35	33	220	33	32	14.3	42	46	1,329	24	25	16.6	45	47
Farmland Industries	903	55	60	90	51	59	10.0	58	68	382	55	59	23.6	17	38
Ferro	478	77	78	17	73	76	3.6	74	82	251	62	65	6.8	67	75
First Mississippi	308	86	89	27	67	73	8.7	62	67	166	68	75	16.2	46	31
Freeport-McMoRan	1,105	46	41	108	47	37	9.8	59	38	876	35	35	12.3	56	32
H. B. Fuller	753	65	65	46	62	66	6.1	69	77	455	52	55	10.1	59	67
GAF	600	68	70	171	37	43	28.5	3	10	na	—	—	na	—	—
General Electric	4,929	8	12	1057	6	11	21.4	19	24	8,023	3	3	13.2	52	69
Georgia Gulf	1,105	46	46	300	22	24	27.2	5	9	473	50	53	63.4	1	3
Georgia-Pacific	253	90	88	na	—	—	na	—	—	na	—	—	na	—	—
B. F. Goodrich	1,977	25	25	261	26	27	13.2	48	49	1,467	22	23	17.8	38	29
W. R. Grace	3,256	15	14	406	18	20	12.5	49	56	2,436	16	15	16.7	44	49
Great Lakes Chemical	792	61	68	202	34	45	25.5	9	13	1,097	29	48	18.4	36	36
Hercules	1,632	30	27	126	42	46	7.7	64	72	1,294	25	22	9.7	61	70

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1989	1989	1988	1989	1989	1988	1989	1989	1988	1989	1989	1988	1989	1989	1988
Hoechst Celanese	$5,658	6	8	$ 576	14	16	10.2%	57	62	na	—	—	na	—	—
Hoffmann-La Roche	500	75	76	na	—	—	na	—	—	na	—	—	na	—	—
Huntsman	1,200	42	40	na	—	—	na	—	—	na	—	—	na	—	—
IMC Fertilizer	1,222	41	44	257	27	33	21.1	20	27	$1,678	21	20	15.3%	48	57
International Flavors	870	57	57	223	32	35	25.7	8	15	684	43	36	32.6	7	27
International Minerals	640	67	53	50	60	50	7.8	63	54	673	44	28	7.4	65	64
Kerr-McGee	592	69	71	125	43	54	21.1	20	29	794	38	46	15.7	47	56
Lawter International	136	98	96	23	69	70	16.5	35	23	134	70	73	16.8	42	34
LeaRonal	157	95	95	16	74	80	10.3	56	70	88	73	76	18.3	37	55
Loctite	457	79	80	80	55	60	17.5	30	45	362	58	58	22.0	23	42
Lonza	450	80	82	na	—	—	na	—	—	na	—	—	na	—	—
Lubrizol	1,124	45	47	321	21	28	28.5	2	8	733	41	44	43.8	4	6
Lyondell Petrochemical	1,905	26	—	na	—	—	na	—	—	na	—	—	na	—	—
Merck	492	76	74	59	58	62	12.0	50	53	470	51	54	12.6	55	58
Mississippi Chemical	209	92	93	47	61	76	22.5	14	66	577	46	60	8.1	64	76
Mobil	4,039	11	10	774	9	9	19.2	26	28	2,702	12	11	28.6	10	13
Monsanto	5,782	5	5	929	8	8	18.1	36	42	4,482	7	7	20.7	28	33
Morton International	935	54	55	144	39	44	15.4	38	40	861	36	40	16.8	42	44
NL Industries	1,001	49	49	278	25	30	27.8	4	12	na	—	38	na	—	12
Nalco Chemical	1,071	48	51	181	35	42	16.9	33	43	939	32	39	19.3	33	43
National Starch	1,569	34	34	226	31	36	14.4	41	51	1,269	26	27	17.8	38	48
Nova Corp.	778	63	—	na	—	—	na	—	—	na	—	—	na	—	—
Nu-West	155	96	—	−3	79	—	def	79	—	170	67	—	def	73	—
Occidental Petroleum	5,203	7	7	1235	4	5	23.7	13	20	5,508	6	6	22.4	21	39
Olin	1,285	38	36	174	36	53	13.5	45	74	936	33	34	18.6	35	67
PPG Industries	1,175	44	42	257	27	31	21.9	16	18	1,033	31	29	24.9	13	26
Petrolite	275	89	86	19	71	74	6.7	68	73	191	65	68	9.7	61	63
Pfizer	509	74	72	39	63	65	7.7	64	69	538	49	52	7.2	66	72
Phillips Petroleum	2,449	20	19	652	11	7	26.6	7	3	1,377	23	24	47.3	3	4
Quaker Chemical	182	94	94	23	69	78	12.7	48	63	109	72	74	21.0	27	59
Quantum Chemical	2,015	24	21	423	17	13	21.0	22	5	1,830	19	21	23.1	19	5
Rhône-Poulenc	1,600	32	35	na	—	—	na	—	—	na	—	—	na	—	—
Rohm & Haas	2,661	18	18	287	23	22	10.8	54	48	2,128	17	17	13.5	51	38
Shell Oil	3,833	12	11	941	7	10	24.5	11	32	3,824	8	8	24.6	14	41
Sherex	188	93	92	na	—	—	na	—	—	na	—	—	na	—	—
Sigma-Aldrich	359	84	85	87	53	57	24.2	12	14	418	54	61	20.7	28	24
Solvay America[a]	1,000	50	50	na	—	—	na	—	—	na	—	—	na	—	—
Stepan	346	85	84	12	77	74	3.4	75	78	215	64	68	5.4	68	64
Sterling Chemical	581	70	64	156	38	24	26.9	6	1	329	59	63	47.5	2	1
Sun Co.	510	73	75	na	—	—	na	—	—	na	—	—	na	—	—
Tenneco	1,224	40	—	119	44	—	9.7	60	—	1,229	27	—	9.7	61	—
Terra Chemicals	949	53	56	na	—	—	na	—	—	na	—	—	na	—	—
Texaco	1,818	27	28	399	19	21	21.9	16	21	1,126	28	31	35.4	6	8
Union Camp	413	83	81	14	76	69	3.3	76	76	289	61	63	4.7	70	70
Union Carbide	7,962	4	4	1225	5	4	15.4	38	26	6,172	5	4	19.8	31	30
Uniroyal	805	60	62	na	—	56	na	—	58	na	—	32	na	—	74
Unocal	1,276	39	39	74	56	40	5.8	70	47	622	45	49	11.9	57	14
Vista Chemicals	779	62	59	227	30	39	29.2	1	16	567	47	51	40.1	5	7
Vulcan Materials	430	82	83	86	54	60	20.1	25	39	na	—	—	na	—	—
Witco	766	64	61	18	72	62	2.3	78	71	377	56	56	4.7	70	50

Note: Companies giving only net profits are not ranked. There are 79 firms ranked for operating profits and operating profit margin, 73 firms ranked for chemical assets, and 72 ranked for return on assets.

Montedison, which has not yet disclosed U.S. results; UGI, which has sold its industrial gas operations; and Products Research & Chemical, 1988's 100th ranked firm, which was acquired by Akzo and which probably would have dropped from the list anyway as bigger companies forced it off. The remaining company, Henkel, would not disclose U.S. sales for 1989.

As in the past, Du Pont is number one in chemical sales in the rankings followed by Dow Chemical, but the gap between the two seems to be narrowing. There is now just a little more than $1 billion separating the two companies and, since Dow has some sales that normally would be classified as chemical in a nonchemical division, the difference between the two companies may be even smaller than that.

In other rankings, Du Pont is number one in identifiable assets devoted to chemicals, having taken over that position from Dow, which was number one in 1988, but falls to second in the 1989 listing.

Dow, however, leads in the operating profits that it derives from its chemical operations, with Du Pont second. These companies held the same positions in the rankings of 1988 results.

In operating margins, both Du Pont and Dow rank far down the list. The operating profit margin (operating profits as a percentage of sales) ranking for 1989 was headed by Vista Chemicals, which was 16th in the 1988 ranking, followed by Lubrizol, which was eighth the year before. Number one in 1988, Sterling Chemical, fell to sixth, and number two, American Petrofina, dropped to 23 in 1989.

For return on chemical assets, the leader was Georgia Gulf, up from third in 1988, followed by Sterling, down from first in the 1988 ranking. Number two in 1988, American Petrofina dropped to eighth place in the latest list. ☐

Industry leaders bullish on biotech outlook

Prospects for success in the 1990s are arising from the groundwork laid in the 1980s by developing biotechnology companies. That's the view expressed by industry leaders at an ACS symposium reviewing and forecasting the state of commercial biotechnology. An increased flow of new products in the 1990s will propel the industry into "long-awaited prosperity," says Roger E. Shamel, president of Consulting Resources.

Although biotechnology products will not dominate the pharmaceutical market, says George B. Rathmann, chairman of Amgen in Thou-

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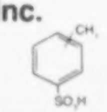

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EPA Proposes Nationwide Recycling Program for Ozone-Depleting CFCs

Program would replace patchwork of state and local rules; chlorofluorocarbons used in auto air conditioners are likely first target

To the satisfaction of both industry and environmental groups, the Environmental Protection Agency is proposing a national recycling program to prevent emission of ozone-depleting chlorofluorocarbons (CFCs) into the atmosphere. In an advance notice of proposed rulemaking (ANPRM) signed April 23 by EPA Administrator William K. Reilly, the agency has asked for comments on the program's scope and on the mechanisms by which it would be carried out.

"EPA has already issued rules under the Montreal protocol reducing CFC production and importation 50% by 1998," Reilly said in a statement accompanying the ANPRM. "Recycling could play a significant supplementary role by reducing emissions and easing the transition to ozone-safe substitutes."

Not just a 50% reduction but a complete phaseout of fully halogenated CFCs by the turn of the century will soon be mandatory. President Bush has already committed the U.S. to that goal and the Senate's version of the Clean Air Act would make that commitment U.S. law. Moreover, the complete elimination of CFCs will become international law when the nations that are party to the Montreal Protocol on Substances That Deplete the Ozone Layer vote in June to strengthen the international treaty.

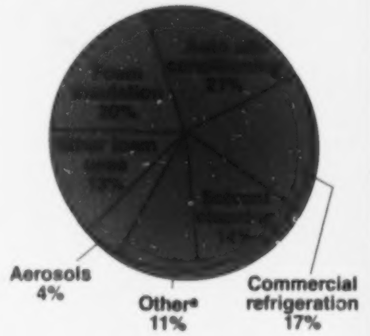
A national U.S. recycling program would have several benefits, according to EPA. It would reduce unnecessary emissions of CFCs from air conditioners and refrigerators. As the phaseout progresses, recycling would conserve the supply of CFCs for use in existing equipment that can't use alternative chemicals. And a national program would check the proliferation of state and local regulations that could result in a confusion of differing standards.

It was the advent of just such state laws that prompted the Alliance for Responsible CFC Policy, a trade group composed of companies that produce and use CFCs, to petition EPA last fall to write national regulations. "We've been anxious to get going and get a national program that will introduce some consistency at the state and local level," says Kevin J. Fay, executive director of the group. "We're pleased EPA has finally put something out."

Also pleased is Liz Cook, ozone campaign director for Friends of the Earth (FOE). Along with the Natural Resources Defense Council, another influential environmental group, FOE has been working with state legislatures on banning certain uses of CFCs and on mandatory recycling for auto air-conditioning systems. "The ANPRM is the first step toward a national program that addresses what we've been working on at the state level," she says.

As has the environmental groups' strategy, EPA's proposed program would focus first on air-conditioning equipment in motor vehicles—the largest single use of CFCs in the U.S. Thanks to a joint voluntary effort by EPA, the auto service industry, and auto manufacturers, standards of purity for recycled refrigerant in motor vehicle air conditioners already exist. Also, a number of companies already are producing equipment for recovering and recycling CFCs from auto air conditioners. Thus, recycling of CFCs while servicing auto air conditioners is technically feasible now.

Recycling feasible for about two thirds of U.S. CFC use



Total 1989 use = 225,352 metric tons

- ▆ Recycling feasible
- ▆ Recycling not feasible

Note: Percentages are of U.S. CFC use in 1986.
a Chillers, sterilization, and household refrigeration.
Source: Environmental Protection Agency

EPA also is considering mandating recycling of CFCs from household refrigerators. Although that technology is not as advanced, Whirlpool has recently developed a multilayer plastic bag that its service technicians can use to capture refrigerant when they make house calls. The agency may later extend the recycling program to CFCs from chillers—air-conditioning systems in large buildings—and commercial refrigeration systems.

EPA is asking for comments on how it should carry out its recycling program. In addition to encouraging voluntary programs, the agency could mandate recycling for specific CFCs uses (direct regulation). Or it could set up a market-oriented program that would provide a financial incentive to recycle. That is, purchasers of CFCs would have to pay a deposit that would be refunded when the chemicals were returned.

Both industry and the environmental groups are opposed to the deposit-refund approach, although for different reasons. "We would not favor market incentives," says FOE's Cook. "That allows someone who has the money to be able to pay to pollute."

"The market initiative is just another excuse for a tax," says the Alliance for Responsible CFC Policy's Fay. The alliance's members are still smarting about the ozone-depletion tax imposed on CFCs in the fiscal 1990 budget law. "We have a feeling there would be a lot more deposits than refunds."

According to EPA's ANPRM, hydrochlorofluorocarbons (HCFCs), which are among the compounds being developed to replace CFCs, might also become subject to mandatory recycling. Although HCFCs have a much shorter lifetime than fully halogenated CFCs, they do carry some chlorine into the stratosphere where it can catalyze the destruction of ozone.

HCFCs' significant, though small, ozone-depletion potentials have made them controversial compounds. Mandatory recycling may turn out to be the least stringent of the possible regulatory fates that await them. International negotiators are still arguing over whether and how they should be included in the new, tougher version of the Montreal protocol. In the U.S., the Senate's version of the Clean Air Act would ban them by 2030.

Although EPA thinks HCFCs are essential for a smooth transition away from CFCs, the agency does not want their use to grow at such a rate that total chlorine concentrations in the atmosphere remain higher than they were when the Antarctic ozone hole first appeared. "Recycling HCFCs," says EPA, "is an essential element of any program to allow for the use of HCFCs to replace CFCs."

The recycling ANPRM will be published soon in the *Federal Register*. Written comments are due 60 days after it appears.

Pamela Zurer

Firms to develop global environmental initiative

Lee M. Thomas, former Administrator of the Environmental Protection Agency, is now helping U.S. companies develop a global environmental management initiative. Thomas' Atlanta-based environmental engineering and consulting firm, Law Environmental, is actively involved in assisting 17 major U.S. firms in setting up this initiative.

According to Thomas, the initiative "is a commitment of the U.S. business community to work with the United Nations and business in other countries to share its experience, know-how, and creativity in the environmental, health, and safety area." The 17 companies are committed to developing appropriate programs, and to funding and staffing them. The participating firms are Allied-Signal, AT&T, Boeing, Dow Chemical, Duke Power, Du Pont, Florida Power & Light, IBM, ICI Americas, Merck & Co., Occidental Petroleum, Philip Morris, Procter & Gamble, Southern Co., Tenneco, Union Carbide, and USX.

The U.S. firms will contribute about $1 million over the next two years for projects yet to be worked out. Formal work plans will shortly be put together by the firms. Their aim is to develop ways of sharing vital information and management expertise with countries desperately in need of such know-how. (Initial candidate countries could include the newly emerging democracies of Eastern Europe.)

Thomas: share experience, know-how

Through the initiative, the companies hope to develop methods for gauging progress made toward environmental, safety, and health objectives, and to encourage the use of such methods. They also plan to prod trade associations and industry groups into tailoring certain of their achievements to environmental, safety, and health objectives. And finally the companies plan to communicate with the public on activities conducted as part of the initiative.

The 17 U.S. companies firmly believe this initiative should be global in scope. To that end, they will design their initiative to support and be coordinated with similar efforts under way in the UN Environment Program, the International Chamber of Commerce (Paris), and the International Environment Bureau (Geneva).

The global dimensions of the initiative are to be stressed at the UN's meeting on sustainable development at Bergen, Norway, later this month. The meeting is being held in concert with the International Chamber of Commerce's Industry Forum on the Environment, which is likely to draw European and Asian businesses into the initiative.

The ICC meeting is expected "to develop an agenda for action for the 1990s," says Susan Vogt, director of Law Environmental's Washington, D.C., office. The U.S. firms intend to participate vigorously in the creation of ICC's agenda, or global charter, for sound environmental management. The charter is expected to be ready for the 1991 World Industry Conference on Environmental Management. And the new U.S. business initiative "should dovetail well with what the ICC wants to do," Vogt adds.

The U.S. firms participating in the initiative expect their numbers to grow, but how this all evolves after the initial two years depends significantly on getting European and Asian participation, and on the outcome of the Bergen meeting.

Lois Ember

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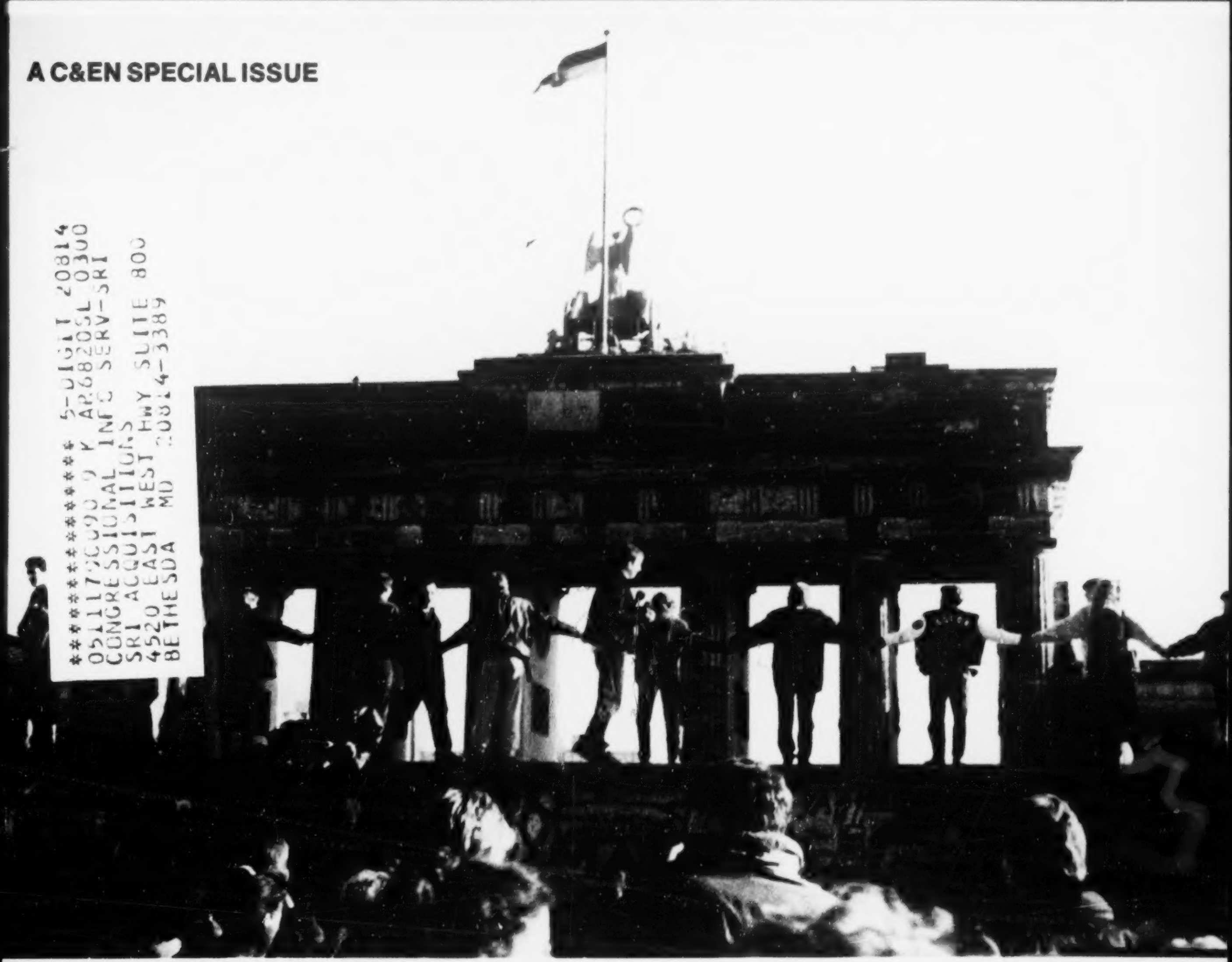
MAY 14, 1990

CHEMICAL & ENGINEERING NEWS

A C&EN SPECIAL ISSUE



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Change Sweeps East Europe

Its impact on chemistry and the chemical industry

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CHEMICAL & ENGINEERING NEWS

MAY 14, 1990

News of the Week

- New initiatives by AAAS, NSF take comprehensive approach to reforming science education. Page 4
- U.S. has offered to stop making binary chemical arms if the Soviets agree to a timetable for destroying their chemical arsenal. Page 5
- Recent raid of White Chemical by New Jersey's criminal justice division turned up a slew of improperly stored drums containing chemicals; no charges have been filed yet. Page 6
- Soon-to-be-released final part of EPA's proposed rules banning land disposal of hazardous wastes already is receiving criticism. Page 6
- Misconduct in science again is getting Congress' attention, with a draft bill circulating that would make it easier to pursue alleged wrongdoings, and with another round of hearings in the offing. Page 7
- Planned Occidental-Soviet joint PVC plant in the Ukraine has been delayed because of local residents' pollution concerns. Page 7

Cover: AP/Wide World photo

Change Sweeps East Europe

Political upheaval has turned East Europe upside down in the past year. This special issue of C&EN explores the impact recent dramatic events there have already had and will have in the future on the chemical industry and chemistry itself. Page 12

The chemical industry

With a population of more than 100 million, East Europe presents a promising market for chemicals. All six of the nations there have well-established chemical industries of their own. But their plants largely are dirty, technically obsolete, and economically inefficient. Bringing them up to western standards will require massive new investments. But until the political climate becomes more stabilized, chemical firms in the West probably will tread with caution. Page 15

Chemical science

Chemistry did not wither under East Europe's former communist regimes. But the climate of isolation and inadequate funding imposed by centralized control and rigid political dogma was far from propitious, either for chemical research or chemical education. Now, with their newly won freedom, scientists in the East are restructuring their operations and organizations. Help from the West would be invaluable, although, at least in the U.S., no clearcut policy for providing assistance has yet emerged. Page 42

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LETTERS

Thermite reaction

SIR: Because the thermite reaction is so widely used as a lecture demonstration, I want to report on an incident that occurred during a "Chemical Magic Show" on March 2. The incident (C&EN, March 12, page 23) involved a traditional thermite reaction carried out in a clay pot with a hole in the bottom for the molten iron to drip into a container of water with sand in the bottom.

Although some uncertainty remains about what happened, we believe that the reaction vessel failed as the reaction reached its maximum intensity, dropping the entire contents into the water. This apparently led to entrapment of water in the molten metal [see Flory, Paoli, Mesler, *Chem. Eng. Prog.*, **65**, 50 (1969)], which resulted in a physical vapor explosion that propelled some of the hot iron into the audience. Although the first two rows of the lecture hall were empty for safety reasons, several members of the audience received minor burns. Fortunately, there were no serious injuries.

In view of this incident (and another similar one reported to me that occurred several years ago in which wet sand was used to collect the hot iron), I would recommend that dry sand be used to receive the hot iron from the thermite reaction. Water should not be present in the container used to receive the iron.

Steven S. Zumdahl
Professor of Chemistry
Director, General Chemistry
University of Illinois, Urbana-Champaign

SIR: With regard to the thermite demonstration-explosion at the University of Illinois, I can recall a related incident that occurred in our laboratory some years ago.

A quantity of silver metal, reclaimed from photographic waste solutions, was melted in a muffle furnace, and most of it poured into a firebrick mold. About 13 g remained, which I intended to convert to mossy silver by pouring into a small beaker full of water. When the molten silver came in contact with the water, the result was a loud explosion, a fragmented beaker, and about 12 g of silver shot. Fortunately, there were no injuries.

In looking back, I do not regard the incident as an experiment that went wrong, but rather the logical result of an error in judgment. I did not adequately take into account the explosive rate at which water would be converted to steam at the temperature of molten silver (>962 °C). Thermite-generated molten iron at a temperature well above 1535 °C would result in an even more rapid conversion of water to steam.

Wilson B. Lutz
Manchester College

SIR: A comment on your Science/Technology concentrates about the thermite demo gone bad. In much the same way, I learned of the ability of the thermite reaction, or rather the molten iron product, to explode in water.

In 1961, I was a photographer for the military documenting the testing of Army materiel under cold conditions in Greenland. A thermite grenade, set on a ⅜-inch piece of iron plate on the snow, was being photographed with a movie camera at fairly close range. As soon as the plate melted through into the snow, an explosion occurred. Fortunately, it was not large and no injuries resulted. Water apparently will thermally decompose and recombine explosively!

A. K. Carpenter
Lower Columbia College

Soot formation

SIR: In regard to the article, "Ideas on Soot Formation Spark Controversy" (C&EN, Feb. 5, page 30), we would like to state that neither one of us has passed judgment, on or off record, on the quality and the results of research in cold fusion, nor did we liken work in cold fusion to work in carbon clusters.

Neither did we classify or refer to the work of Richard Smalley and Harry Kroto on carbon clusters or the work in cold fusion as "pathological science," either in the everyday meaning of the word pathological or in the specific meaning described by Langmuir [Langmuir, *Physics Today*, **42**, (10), 36 (1989)].

Lawrence B. Ebert
Exxon Corporate Research Laboratory
Annandale, N.J.
Michael Frenklach
Fuel Science Program, Department of
Materials Science and Engineering
Pennsylvania State University

Editor's Note: Baum's characterization of the tone of the dispute over soot formation is based on, and inferred from, interviews and correspondence with the parties involved. In letters to C&EN, Ebert and Frenklach both state that issues raised by C&EN editorials that were highly critical of the premature and excessive promotion of cold fusion were relevant to earlier C&EN coverage of

Continued on page 68

Chemical Industry

113 million consumers make East Europe a tempting market and its chemical industry needs rebuilding, but investment there could be risky

Patricia L. Layman, C&EN London, and **Earl V. Anderson,** C&EN Northeast News Bureau

"If Europe were once united in the sharing of its common inheritance, there would be no limit to the happiness, to the prosperity and glory which its three or four hundred million people would enjoy." So said Winston Churchill, accepting an honorary degree from the University of Zürich in 1946, half a year after he coined the phrase "Iron Curtain" in an address at Westminster College, Fulton, Mo.

It is a shame, then, that the British statesman could not have been on the scene in Berlin on Nov. 9 last year, when that Iron Curtain was irrevocably shattered.

It wasn't Joshua fighting the battle, and it wasn't a trumpet that blew down the Iron Curtain. Rather, it was the moral pressure of hundreds of thousands of citizens. But the walls came tumbling down, nevertheless. What occurred in Berlin last November was only perhaps the most vivid event in the wave of human demand for freedom. The grand practical text of Marx's theories, in the U.S.S.R. since 1917 and the rest of East Europe since the end of World War II, came to an end with breathtaking quickness.

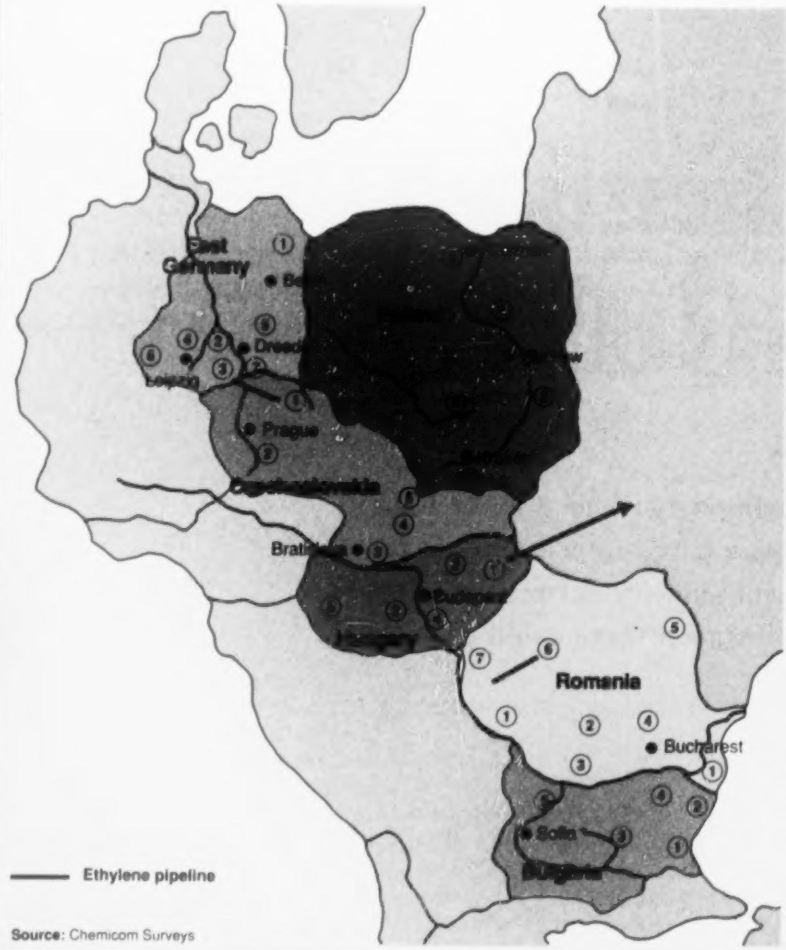
And just as the symbolic tumbling of the Berlin wall—which less than a year before had seemed secure for the foreseeable future—has opened opportunities for human and economic development in the East European countries, so has it also opened opportunities for the development of the East European chemical industry. Such development will come from internal efforts, but even more important, from partnerships with industry in both the West—West Europe and North America—and the Far East.

The very fact that people in both East and West Europe are talking about development of the chemical industry—or perhaps, more precisely, its redevelopment—shows enormous optimism. For there are major problems attendant to any development in East Europe—and not just of the chemical industry. It is easy to tick off some of the problems:

- Lack of money, especially hard currency.
- Small populations, which will be even smaller if ethnic pressures break up some of the nations.
- Old plants and outdated technology, which inefficiently produce goods of unsatisfactory quality.
- State-owned, unproductive industries, usually wildly overstaffed.
- Severe environmental problems.
- Dependence on imported raw materials, in most of the countries.

These problems raise a number of questions—far more than, as yet, there are answers. For example, how will East European industries cope with the lack of foreign currency, which used to be provided by the central governments or appropriate ministries? How will they tap into development funds being set up by various banks and governmental agencies? How will they coexist with their counterpart industries, particularly in the European Community (EC), which—while aware, concerned, and interested in what is happening in East Europe—is marching toward its own single market by the end of 1992?

In addition to the general economic problems and questions hanging over the economies of East Europe, the chemical industries there also have their own special problems. At stake are industries that are sometimes even more significant to their countries, in terms of their contributions to gross national products and exports, than the chemical industries in West Europe or North America. Chemistry and the chemical industries in East Europe, indeed, have an honorable history, being the birthplace of a variety of technologies, ranging from the original Haber-Bosch ammonia process, in what is now East Germany, to poly(methyl methacrylate),



Source: Chemicom Surveys

East Germany

1. Schwedt: petrochemicals, fertilizers, aromatics
2. Schkopau-Halle-Bitterfeld: inorganics, plastics, synthetic rubber, chloralkali, pesticides
3. Böhlen: petrochemicals, aromatics
4. Leuna: plastics, pesticides, petrochemicals, fertilizers, pharmaceuticals
5. Schwarzheide: urethanes, herbicides
6. Sondershausen: potash
7. Dresden: pharmaceuticals

Poland

1. Plock: petrochemicals, plastics
2. [illegible] area: sulfur, fertilizers
3. Krakow-Katowice: inorganics, synthetic rubber, fertilizers, plastics
4. Wloclawek: fibers, fertilizers
5. Blachownia: coalchemicals
6. [illegible]

Czechoslovakia

1. Litvinov: petrochemicals, fertilizers, plastics
2. Prague area: plastics, fibers, petrochemicals, chloralkali, fertilizers, synthetic rubber
3. Bratislava area: agrochemicals, fibers, fertilizers, pharmaceuticals, plastics, petrochemicals
4. Duslo Sala: fertilizers
5. Novaky area: chloralkali, plastics, petrochemicals, rubber products

developed for soft contact lenses in Czechoslovakia.

For the chemical industries in East Europe, other questions pose themselves. For example, how will they cope with environmental pollution problems of massive proportions? How will their structures have to change, to adapt to changing conditions and requirements that are being placed on the industry? How will they cope with privatization? How will they cope with the disintegration of the Soviet-bloc Comecon trading structure? And how will the kinds of products now being produced in East Europe have to change, in terms of quantities and plant locations.

That changes will occur there is no doubt. However, factors such as the direction of those changes and their pace and magnitude are unknowns. That such changes will have significant impact on the world's economy is also not disputed. For example, American Express Bank, in the latest issue of its *AMEX Bank Review*, suggests that economic reform in East Europe could eventually add 10% to world trade. However, the pace of change will be limited by the speed of price reform and the creation of a satisfactory structure for foreign investment, the review adds.

In the very long term, the review says, trade from East European countries will come into line with average per capita trade in the EC. For the next five years, however, with reforms, the region could achieve a 10 to 20% per year rate of growth in exports, adding 1 to 2.5% to existing world trade, or between $31 billion and $76 billion.

If for no other reason than propinquity, West Europe will be on the front line of the efforts to help redevelop the industries and economies of East Europe. West Europe, under the aegis of the EC, for example, has been entrusted with the administration of the PHARE program—Poland/Hungary Assistance in Restructuring Economies. That program, established last summer, has since been extended to include East Germany, Bulgaria, Czechoslovakia, Romania, and Yugoslavia.

The geographic nearness of the East European countries also has, over the centuries, built a legacy of cultural and commercial ties that bind, that not even a postwar split has changed. For example, West Germany is busy now working out details of reunification with East Germany, with its chemical industry one of the major industrial sectors involved in counterpart discussions. And Austrian industrialists are finding success in Hungary.

Meanwhile, the East European members of the Council for Mutual Economic Assistance (CMEA) are working to rebuild bridges back to the rest of Europe, even as the EC it-

Hungary
1. Leninvaros: plastics, fertilizers, petrochemicals
2. Százhalombatta: aromatics
3. Kazincbarcika: plastics, fertilizers, organic chemicals, chloralkali
4. Budapest: fertilizers, plastics, pharmaceuticals, pesticides
5. Lake Balaton area: organic chemicals, fertilizers, aromatics

Romania
1. Midia-Nåvodari: aromatics, ethylene, propylene, plastics, fertilizers
2. Pitzst: petrochemicals, plastics, carbon black, herbicides, chloralkali, inorganics
3. Craiova: acetylene-based organics, fertilizers
4. Ploiesti: petrochemicals, synthetic rubber, fertilizers
5. Borzesti: petrochemicals, synthetic rubber, chloralkali, fibers, fertilizers, pesticides
6. Timisoara: petrochemicals, pharmaceuticals
7. Arad: fertilizers

Bulgaria
1. Burgas: petrochemicals, fibers, synthetic rubber, plastics
2. Devnia: chloralkali, polyvinyl chloride, fertilizers
3. Kazanlák: essential oils
4. Razgrad: pharmaceuticals
5. Vratza: fertilizers

self is accelerating its pace toward the economic, monetary, and political union implicit in the single market of 1992.

The EC pace has become so rapid—and irrevocable enough—that non-EC countries in the West are contemplating applying to join. Even as the EC is negotiating extensive trade agreements with the nations of the European Free Trade Assn., for example, EFTA members are giving serious thought to joining the EC. Austria already has applied to join the EC, and political observers expect Norway to do so this year.

Hence, in a way, it comes as no surprise that the East European countries find the possibility of EC membership intriguing. At least one political observer has predicted Hungary will be a member of the EC by the end of this decade and that other CMEA countries will have at least applied for membership.

Such membership would offer the promise of what western countries consider normal trading patterns, normal financial relations, normal supply-demand markets. And one of the major beneficiaries will be the chemical industry—albeit after many changes to the industry in East Europe. What the industry is suffering from now stems from such factors as the legacy of four and a half decades of five-year planning, of dependence on the natural gas and oil resources of the Soviet Union, and, particularly in East Germany, dependence upon coal as a chemical feedstock.

East Germany: East Europe's top chemical producer

East Germany has the largest chemical industry in East Europe, except for that of the Soviet Union. Most of its industry is organized into combines, points out a study on the East bloc by London-based Chemicon Surveys, whose directors, Tony Cox and Natasha Alperowicz, have monitored the East European chemical industry for the past 10 years. These combines are amalgamations of industrial firms controlled by a single management, and having their own industry minister. With the move to reunification with West Germany progressing quickly, it is clear that the role of these combines will soon be changing, but for now, they still are the dominant structural force for industry in East Germany.

Chemicon's most recent survey, "On Course to Reform: the East European Chemical Industry 1986–1990," hinted at some of the changes that Cox and Alperowicz think will be taking place throughout the East bloc. It also examines the various combines in the industry. The chemicals and minerals industries account for 16 of the country's 129 combines and employ nearly 350,000 workers. Most of the industry—about 70%—is based on oil, but coal still accounts for about 15% of the chemical industry's feedstock, through carbide-acetylene.

With its 27,500 employees, Petrochemisches Kombinat Schwedt, is the largest and newest combine. It refines 80% of East Germany's crude oil, and produces about 33% of its chemicals, making more than 400 different products ranging from aromatics and nitrogen fertilizers to pure laboratory chemicals and consumer products, including household aerosols and shoe polish.

Chemiekombinat Bitterfeld employs 30,000 workers in seven factories to make about 4000 products. These include inorganics, dyestuffs and intermediates, chlorine and caustic soda, fluorocarbons, silicones, photochemicals, rubber chemicals, and fabricated plastics goods, as well as about 60% of East Germany's agrochemicals. Bitterfeld has been cited as one of the most highly polluted chemical centers in East Germany.

In the same region, at Schkopau, Chemische Werke Buna also has 30,000 employees, making about 11% of East Germany's chemicals. About 60% is synthetic rubber; the combine also makes calcium carbide, polyvinyl chloride, polyethylene and polyester resins, plastics additives, solvents, and consumer goods.

Sondershausen's Kombinat Kali exploits the country's vast potash deposits, but also makes a variety of other mineral products. Fiber production, both cellulosics and noncellulosics, is dominated by Chemiefaserkombinat Schwarza, at Rudolstadt-Schwarza, making nylon, polyester, acrylic, and polyvinyl fibers. Kombinat Agrochemical Piesteritz specializes in nitrogen and phosphate fertilizers and pesticides.

And in Leuna—historical home of the Haber-Bosch ammonia process—the combine Leuna-Werke Walter Ulbricht accounts for about 12% of East Germany's chemical production. Leuna, with its ethylene cracker, is strong in basic petrochemicals, plastics, detergents, and gasoline additives, as well as more downstream products such as pharmaceuticals, rare gases, and electronics chemicals. The country's acetylene chemistry operations are based there and at Schkopau.

Poland: Coal still an important raw material

Unlike East Germany, the chemical industry in Poland has not been organized into combines; much is still handled by separate enterprises. Chemicon Surveys, for example, estimates that by the end of the 1980s, 75% of investment in the chemical industry was covered by individual enterprises.

In a country dependent upon Soviet imports for 95% of its oil and for all its natural gas, but self-sufficient (indeed, an exporter) in coal, coal chemistry is a strategically important option where the economics are favorable. For example, more than 1 million metric tons of coal tar and benzole are processed annually into aromatic chemicals—accounting for 53% of the country's total toluene production, 40% of benzene production, and 7% of phenol production. Acetylene is still an important raw material for a variety of other chemicals, including synthetic fibers.

One major petrochemical center of Poland is Plock, where operations are based on trouble-plagued ethylene units. Another is at Blachownia, which also produces coal chemicals. Plastics—low-density polyethylene, polypropylene, polyvinyl chloride and polystyrenes—are produced at Plock, Oswiecim, Tarnow, and Wloclawek; other units concentrate on polyesters, epoxies, and fluoropolymers. Synthetic leather, based on the Du Pont Corfam technology, is produced at Pionki, southeast of Warsaw.

Oswiecim, the Polish name for Auschwitz, is the synthetic rubber center of the country, producing styrene-butadiene rubber, polybutadiene emulsions and styrene resins, as well as synthetic rubber and latex.

Poland is one of the world's major producers of sulfur, using both open-cast mines and Frasch technology: The country has about 30% of the world's reserves. The Skopanie area, centered around Tarnobrzeg, is the focus of this industry, where sulfuric acid, a strong Polish industry, also is produced. In addition, this region is a center for production of both nitrogen and phosphate fertilizers. Potash fertilizers are imported from the U.S.S.R. and East Germany.

According to Chemicon, Poland's application rates of agrochemicals are among the lowest in Europe, and lower than in any other CMEA member country. Only about 40% of the pesticides registered for use are produced in Poland, including some made under license; domestic production is mainly of old, first-generation products.

On the other hand, in inorganics, the country does better. Inowroclaw, for example, is a major site for chloralkali production, using nonmercury technology. And the country is a leading producer and exporter of organic dyes and pigments; about 80% of the country's production comes from Zgierz, near Lodz. The Boruta works at Zgierz produces 20 groups of dyes, including direct, to nigrosine, aniline, reactive, stilbene-azo, and food dyes.

Czechoslovakia: Specialty chemicals are important

Compared with most other East European countries, Czechoslovakia gives less emphasis to petrochemicals than it does to other chemical sectors, primarily because of the country's dependence on oil from the U.S.S.R. Instead, the country stresses less energy-intensive, high-value-added specialties, including rubber chemicals, synthetic fibers, and textile auxiliaries.

Because the country is a federation of two republics—the Czech (Moravia and Bohemia) and the Slovak—its industry tends to have many duplicate features. For example, the country's chemical industry is not solely under the aegis of a minister of the chemical industry but also is under the National Ministries for Industries, of which there is one in each of the two republics. And two management organizations—Chemopetrol, in the Czech Republic, and Slovnaft, in Slovakia—handle petrochemicals, based on ethylene crackers at Litvinov and Bratislava.

Litvinov's production includes a variety of petrochemicals and plastics—high-density polyethylene, oxo alcohols, aromatics, and α-olefins.

Slovnaft's production, at Bratislava, includes low-density polyethylene, ethylene oxide and glycols, polypropylene, and dimethyl terephthalate. Its greatest emphasis, however, is on rubber chemicals, including vulcanization accelerators and inhibitors, antioxidants and antiozonants, and plasticizers.

Polyvinyl chloride production is split between Novaky, in Slovakia, and Neratovice, in Bohemia; polystyrene and acrylobutadiene-styrene resins are produced at Kralupy, just

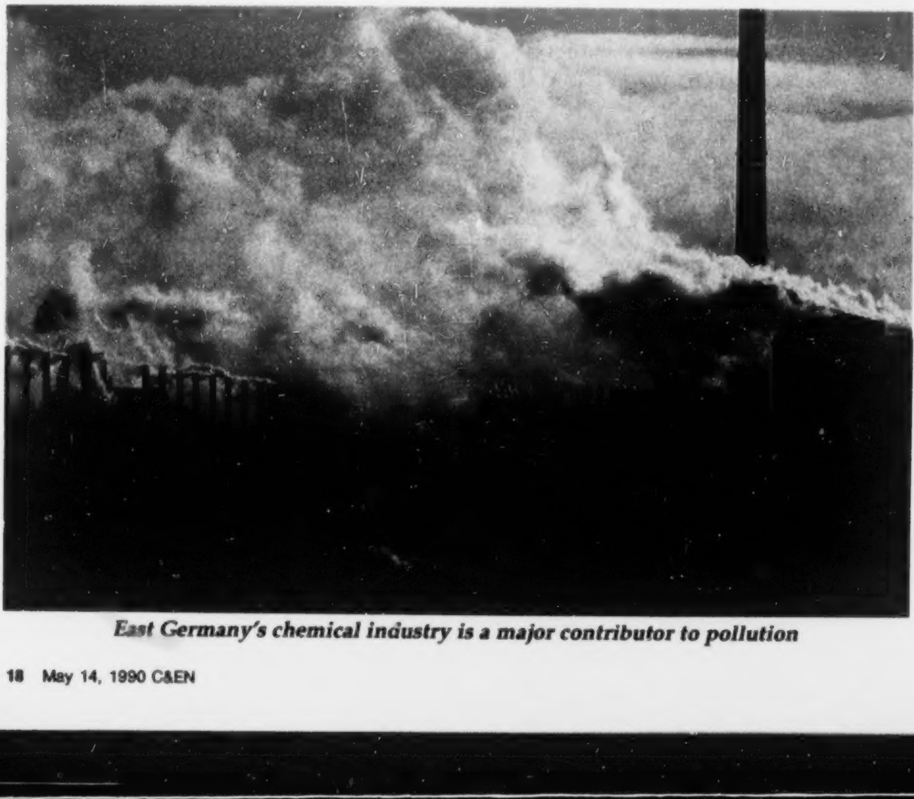


Photo by TIME magazine's Peter Jordan

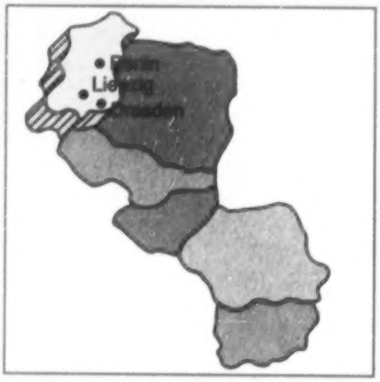
East Germany's chemical industry is a major contributor to pollution north of Prague. Poly(methyl methacrylate)—the original soft-contact lens material—is produced at Zilina, in Slovakia.

Synthetic fibers—especially polypropylene fibers and cellulosics—are increasingly important to Czechoslovakia, which otherwise must import natural fibers such as wool and cotton. The country is a major producer of polypropylene fibers worldwide, using its own technology. But nylon and polyester fibers are also important, with production tending to be located in Slovakia.

A net importer of inorganic chemicals, Czechoslovakia is heavily dependent on imported raw materials for fertilizers, for example, which it produces at Litvinov, Strazske, and Duslo Sala. Similarly, the country imports soda ash to augment domestic supplies, particularly to support its glass production, an important national industry. Major chloralkali capacity is at Neratovice, using mercury-cell technology.

Raw materials for both pharmaceuticals and agrochemicals must be imported, but the country is nonetheless working to build up its domestic production in these sectors. Agrochemicals are produced primarily at Neratovice and at Slovnaft's facilities at Bratislava and Duslo Sala. Pharmaceuticals are made at a variety of sites around the country, with development supervised by the State Institute for Drugs Inspection and the Commission for New Drugs, part of the Czech and Slovak Ministries of Health.

The country is also devoting increased attention to biotechnology, with its research institutes working on genetic engineering, microbiology, and environmental protection.



East Germany in brief

Size: 41,768 square miles

Population (1989): 16.6 million

GNP (1988): $207.2 billion

GNP per capita (1988): $12,500

World trade:

Imports (1988): $29.6 billion

Exports (1988): $30.7 billion

Telephones per 100 people (1985): 22

Automobiles registered per 1000 people (1986): 209

The most industrialized of the East European nations, East Germany was established in 1949 from the part of the ruins of Nazi Germany that was controlled by the Soviet Union. It consists of a sprawling northern lowland and a smaller but rugged southern highland.

The most important of the relatively sparse mineral resources are lignite, potash, and rock salt. Major industries include steel, chemicals, electrical products, textiles, and machinery. Main crops are grain, potatoes, and sugar beets, but the country has a food deficit. Important imports include fuels, foodstuffs, and machinery. Steel, chemicals, machinery, and motor vehicles are significant exports.

Until the fall of the Honecker regime late last year, East Germany's economy and political life were rigidly controlled by the central government, which firmly resisted reform; economic growth had been relatively slow. Now, the increasing likelihood of early reunification with West Germany sets East Germany distinctly apart from other East European nations.

Hungary: Pharmaceuticals are key products

The chemical industry of Hungary is currently one of many industrial groups under the Ministry of Industry. Hungary was the first CMEA country to allow western joint ventures, and since 1982, it has permitted foreign partners to own majority shares in Hungarian enterprises. The chemical industry employs between 110,000 and 120,000, in 86 enterprises and 356 industrial plants, and is the nation's second largest industrial sector after mechanical engineering, according to the definitions the country's statisticians use.

About 40% of output is in oil refining, followed by pharmaceuticals, at 13%. Gas production and distribution, and fertilizers and other agrochemicals each account for 11% of production; plastics, fibers, rubber chemicals, cosmetics and toiletries, and miscellaneous specialties make up the remainder.

The country's aromatic chemicals industry is centered around a refinery at Szazhalombatta, producing benzene, toluene, xylenes, and maleic anhydride. Petrochemicals are based at the Tiszai Vegyi Kombinat (TVK) unit at Leninvaros: The olefins plant there produces ethylene, propylene, C_4 and C_5 fractions, and gasoline-blending components. Leninvaros is at one end of an ethylene pipeline from Kalush, in the Soviet Union, which supplies ethylene in exchange for fiber-grade polypropylene.

Part of the ethylene goes into linear low-density polyethylene. Hungary is surpassed only by Czechoslovakia in plastics consumption per capita, and the plastics industry is important to Hungary. It produces a wide range of plastics and resins, including polyvinyl chloride, polyolefins, amino and alkyd resins, epoxies, maleic resins, and silicones. Kazincbarcika, site of the Borsod chemical combine BVK, is a major polymers site; polymers are also produced at Leninvaros.

In fibers, Hungary specializes in acrylics, followed by cellulosics, polypropylene, and nylon fibers. Production is based at the Magyar Viscosagyar complex at Nyergesujfalu, on the Danube River northwest of Budapest. But synthetic fibers are not a major industry.

By contrast, fertilizers are of great significance to Hungary, which has six major complexes throughout the country. Nitrogen fertilizers are produced at Varpalota, Kazincbarcika, and Leninvaros; phosphate and nitrogen-phosphate-potassium fertilizers at Peremarton, Szolnok, and Budapest. For other agrochemicals, however, the country has only limited production; its industry relies heavily on formulation and cooperation agreements with western firms, Chemicon Surveys points out.

It is in pharmaceuticals that the Hungarian industry has sparkled. It accounts for about 5% of world trade in pharmaceuticals, with about 60% of its production bound for the export market. Pharmaceuticals represent more than 13% of the industry's production value, and account for nearly 5% of the nation's total exports. Exports consist primarily of active ingredients for older, commodity-type and generic drugs; production is handled primarily by the country's six major pharmaceuticals producers, mostly based in Budapest.

Bulgaria: Fertilizer chemicals have a major role

The chemical industry in Bulgaria is overseen by an association of the biotechnology and chemical industries, made up of member enterprises in the biotechnical, chemical, medical, food, and engineering sectors.

There are two main petrochemical centers in Bulgaria, at Burgas and Pleven, near the border with Romania. Burgas, which is by far the larger, uses feedstock oil from the U.S.S.R.; with an integrated downstream petrochemical capacity, it accounts for slightly more than a third of the country's total chemical production. Included are olefins, aromatics, ethylene derivatives, ethanol, alkylates, and paraffins. The complex also produces plastics, synthetic fibers, and synthetic rubber. Production of polyethylenes, polystyrene, and polypropylene is based there.

A plant at Devnia, further north along the Black Sea coast, is the center of Bulgaria's chloralkali production and also makes polyvinyl chloride and plastisols. And a plant at Verila, southeast of Sofia, produces polyols, for urethane production at Ruse, along the Danube to the north.

Burgas also produces acrylic and polypropylene fibers. Other fiber facilities include Yambol, in eastern Bulgaria, which produces polyester staple and filament; Vidin, in the far northwest corner of the country, which makes nylon; and Svishtov, along the Danube, which manufactures viscose.

Much of Bulgarian industry is devoted to food and agricultural products, so that fertilizers are particularly important. The country has four main fertilizer complexes: Dimitrovgrad (the largest), Stara Zagora, and Vratza, all in central Bulgaria, and Devnia. Plovdiv is the leading agrochemicals site, with smaller pesticide plants around Sofia.

Pharmaceuticals are also a specialty for Bulgaria, which exports nearly 80% of its production, primarily to other CMEA countries. The country claims to be the world's leading exporter of antibiotics—an indication of the importance the nation places on biotechnology, which perhaps is more important to Bulgaria than to any of the other CMEA countries. From a start in 1961, Bulgaria now specializes in antibiotics, amino acids, enzymes, and plant-protection compounds for human and animal health applications, the food industry, and other industrial applications.

Bulgaria also has a highly prized business in one of the more exotic specialties—rose oil. This essential oil, from the rose fields around Kazanlak, is considered by perfumers to be one of the best ingredients for fine fragrances and carries a price tag that can run to thousands of dollars per kilogram.

Romania: Chemical industry oriented toward oil feedstocks

In Romania, the chemical industry has been governed by the Minister for Chemical and Petrochemical Industry, who, in turn, reports to the Council for Ministers. It consists of 85 enterprises, with 220,000 employees, and represents probably about 10% of the country's total industrial output.

Romania is the only country in East Europe, other than the Soviet Union, with indigenous oil and gas reserves, which have been worked since before World War I. These fields have to a large extent been depleted, and the country tops off its supplies with imports from the U.S.S.R. and the Middle East; however, it still is an exceedingly heavy energy user. Oil processing and petrochemicals account for 55% of Romanian chemicals production, with about 15% of the country's oil consumption used in the petrochemicals industry, Chemicon Surveys estimates.

The country's largest petrochemicals complex is at Pitesti, with ethylene, propylene, butadiene, and aromatics capacity. Downstream units make acrylonitrile, ethylbenzene, ethylene derivatives, and mercap-

Greenpeace Communications photo

Gdansk is a major fertilizer producing site in Poland tans, and other products. Pitesti also produces low- and high-density polyethylenes, polystyrene, latices, and carbon black.

Petrochemical complexes at Midia, Borzesti, and Timisoara also produce a wide variety of olefins, polymers, and petrochemicals. For example, Midia produces high-density polyethylene, polypropylene, propylene oxide and styrene. Timisoara supplies polypropylene, phthalates, caustic soda, oxoalcohols, polyether polyols, and even has a fermentation unit for ethanol. The Borzesti complex has one of the widest product ranges, producing about 260 different chemicals, from acetylene to chlorinated paraffins to styrene butadiene rubber.

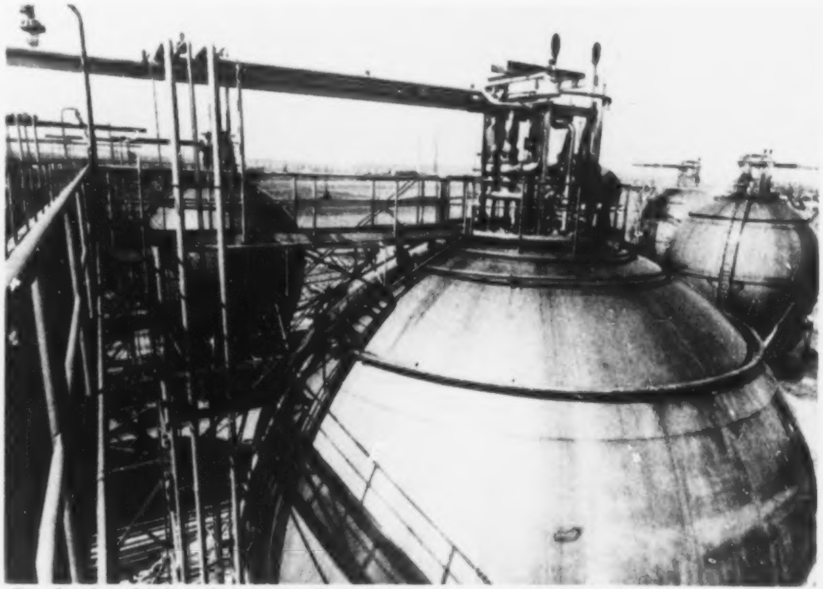
Organic chemicals are the specialty of Craiova, which uses acetylene derived from natural gas cracking; products include methanol and acetic acid and its derivatives.

Romania is East Europe's third largest producer of synthetic fibers, after the U.S.S.R. and East Germany. It specializes in cellulosics, but also makes polyester, nylon, and acrylic fibers. The country is also a major exporter of fertilizers, capitalizing on its natural gas reserves. For example, it is the leading East European supplier of urea to the world market, after the Soviet Union. Production of fertilizer is coordinated at Craiova, with major plants for nitrophosphate fertilizers at Arad, Craiova, Tirgu-Mures, and Tirgu-Măgurele.

Major chloralkali capacity is at Govora and Rimnicu Vilcea, both near Pitesti, and at Borzesti.

CMEA agreements split up chemical output

Throughout the past decade, the CMEA countries have, through a complex series of bilateral agreements and understandings, divided the chemical world according to specialized strengths. For example, Romania was the major CMEA source for polyisoprene rubber, chlorine derivatives, and soda ash. Czechoslovakia focused on rubber and textile specialties, dyes, and polypropylene fibers. Poland exported paints and coatings, detergents, organic dyes, and pharmaceuticals. For Hungary, the areas of specialization included medicines, agrochemicals, plastics, and rubber goods. From East Germany, it was photochemicals, dyestuffs, and herbicides. And Bulgaria specialized in selected agrochemicals, dyes, varnishes, chemical reagents, catalysts, and plastics. Energy-intensive products were, under this basic integration plan, to be produced by the Soviet Union, which, of course, had the basic feedstocks at hand.


Czechoslovakia's only styrene/butadiene rubber plant is at Kralupy, near Prague

Over the past five months, however, the situation has broken down. Always more honored in the breach than the observance, the agreements have suffered as the whole concept of the CMEA itself foundered. In fact, last month, Prague announced that Czechoslovakia was pulling out of three multilateral CMEA agreements. The U.S.S.R., which has built its own production plans based on the CMEA trade agreements, already is concerned that East Germany, for one, will not continue to supply it with imports as promised.

To some extent, the problem is one of the Soviet Union's own making. One of the major topics of discussion at the 5th Annual Conference on Soviet and East European Business Prospects, held last month in London, by PlanEcon Inc., of Washington, D.C., and DRI/McGraw-Hill, was the decision of the Soviets to begin charging world market prices for the oil and gas it provides its former satellites.

With the end of the subsidies that the U.S.S.R. had been giving and its insistence that its invoices be paid in hard currency, the East European countries will be forced to concentrate on gaining that currency in whatever way possible—even if it means selling to the West, rather than back to the U.S.S.R. "Prices that had very little to do with world pricing are about to change," pointed out PlanEcon president Jan Vanous, "and the impact will be profound."

As things stand now, most chemical industry executives would probably agree with Ray R. Knowland, a managing director of British Petroleum and chairman of BP chemicals: "We are looking with considerable interest but no strategy per se. I'm sure there will be opportunities. However, I doubt many western countries will rush in to the East bloc, without trading partners of some sort. It is not too soon to have an interest, but too soon to have a strategy."

As Günter Metz, president of the European Chemical Industry Federation (CEFIC) puts it, "Just a few months ago, who would have thought that on Christmas Day people from East and West would be able to go through the Brandenburg Gate so easily, or that Vaclav Havel,

Biggest volume of East Europe's chemical output is in inorganic chemicals

Production, thousands of metric tons	Bulgaria	Czechoslovakia	East Germany	Hungary	Poland	Romania
Sulfuric acid						
1980	852	1285	958	590	3019	1756
1985	810	1297	882	520	2863	1835
1988	780	1249	799	512	3166	1650[a]
Hydrochloric acid						
1980	50	225	106	78	na	289
1985	74	236	137	121	na	447
1988	73[b]	247	132	113[c]	na	445[a]
Nitrogen fertilizer (100% active)						
1980	730	618	943	649	1290	1707
1985	838	526	1078	684	1254	2197
1988	948	596	1382	556	1622	2315[b]
Benzene						
1980	na	184	na	104	240	na
1985	na	291	na	120	232	na
1988	na	358	na	116[c]	238[b]	na
Ethylene						
1980	150	323	na	275	185	na
1985	242	592	na	270	261	na
1988	na	683	na	264	276[b]	na
Polyethylene						
1980	93	216	119	53	111	124
1985	105	259	187	56	142	163
1988	107[c]	267[b]	203[c]	221	145[c]	150[c]
Polystyrene						
1980	16	61	53	na	34	32
1985	25	86	51	na	23	34
1988	25[c]	74	46[c]	na	22[c]	32
Polyvinyl chloride						
1980	64	204	260	173	119	206
1985	98	209	301	170	126	204
1988	22[c]	219	269[c]	193	189	208[c]
Thermoset resins						
1980	16	91	180	51	135	180
1985	406	92	233	49	145	na
1988	322[c]	94	251[c]	40	160	na
Synthetic fibers[d]						
1980	55	112	139	21	168	141
1985	61	139	158	24	165	185
1988	60[c]	146	178	33	168	184[c]
Synthetic rubber						
1980	30	60	118	na	118	150
1985	26	70	161	na	126	156
1988	25[b]	77	70[b]	na	127	152[c]
Paints and varnishes						
1980	105	244	380	122	416	182
1985	130	262	397	134	408	184
1988	151[c]	268	406[c]	139[c]	404[c]	178[c]

a PlanEcon estimates. b For 1986. c For 1987. d Noncellulosic fibers only. na = not available. **Source:** PlanEcon

playwright and former dissident, would now be President of Czechoslovakia. The political and economic reforms under way in the East bloc have brought Europe closer together. We are pleased that CEFIC has already established some contacts with chemical industry federations there, particularly in Poland and Hungary."

These organizations include the Hungarian Association of Chemical Industry, and the chemical section of the Hungarian Chamber of Commerce, and the Chamber of the Polish Chemical Industry.

"We welcome the opportunity to set up a dialogue with Poland and Hungary," says Hugo Lever, director general of CEFIC. "Providing these countries move further towards a free-market economy, it is probable that in the medium term, the chemical industry associations of these countries could become CEFIC members."

West Germany is moving fastest to form partnerships

West Germany is setting the pace in forming partnerships with companies from East Europe, says Peat Marwick McLintock, a management consulting firm. Some 120 partnerships were formed between West Germany and East European firms in the first quarter of 1990, compared with only 42 in the preceding quarter, the company says.

"The West Germans are there, and their people are looking at the plants, forming joint ventures. The other countries' companies are doing things like setting up sales offices," says Alistair Kilgour, chemicals analyst with BNP Securities, in London.

"At the moment, these assets are not worth much. But an injection of cash and technology would change that. The West Germans' main message is that plants are out of date. But the customer base is there. If they can get hold of assets and a customer base, you can look at it in two strategic ways: on an aggressive side, it gives them new markets; it also is defensive, in a way, because it keeps others out."

Kilgour believes, for example, that the latter is one reason the Belgian producer, Solvay, is so set on regaining the soda ash facilities expropriated in East Germany. Partly it is a deeply felt matter of ownership and justice; the company never relinquished its rights to the soda ash plants. But, adds Kilgour, it is also a defensive move: If someone else got hold of that plant, Solvay's strong position in the soda ash market in West Europe could be shaken.

Meanwhile, the East German chemical industry has set up a trade association, the Verband der Chemischen Industrie (association of the chemical industry). That also is the name of the counterpart association in West Germany, which was founded in 1877 in Berlin.

West Germany's VCI, which is now headquartered in Frankfurt, has set up a "Verbindungsstelle"—a unification post—in Berlin, with three staff specially charged with East German concerns. It will focus on the impending union with East Germany, and will serve primarily as a backup partner on environmental questions, providing technology that the West has developed for solving environmental problems to counterpart industry in the East.

Productivity in East Germany—by one estimate, less than half that of West Germany—could realistically double in the next 10 years, predicts German Economy Institute in Cologne. It expects an average increase of 7.2% per year over the next decade. That would bring an average growth rate of 7.5% and a standard of living roughly equivalent to that in West Germany today by the turn of the century. Such growth, the institute adds, could clear up any unemployment problems in East Germany, which are bound to occur as firms struggle to become less overstaffed and more efficient.

West Germany already has the largest chemical industry in Europe, and the East German sector could boost sales by another $58 billion per year. However, if West German environmental standards are applied, as much as 60 to 70% of East Germany's chemical industry could be forced to shut down, especially chemical plants based on lignite.

In a discussion paper for EC heads of state and government, the European Commission set out implications for the community of German unification, and antipollution measures were high on the agenda. The paper points out that East Germany is one of the last countries still operating a large coal-based chemical industry and that a distinction will have to be made betweeen plants where pollution is too high to be eliminated—ones that will have to be closed—and those to which antipollution equipment could be fitted.

The developed nations have begun working out aid packages to help East Europe clean up its environmental problems, among other projects. For example, the EC has agreed on a statute to establish a Bank for Reconstruction and Development of Europe.

The EC has also agreed to put together a comprehensive aid package for the environment in East Europe. Training programs and transfer of technology will be key elements in the package, which is likely to cost billions of dollars. The EC called for an environmental code of conduct to be drawn up for EC-based industries locating in East Europe, so that they do not import new problems.

The formal program to give environmental aid to East Europe will be framed at an East-West meeting in Dublin on June 16. The meeting will be the first of any kind at ministerial level between the EC and the new East European countries. It will provide the first detailed balance sheet of the environmental degradation in the East.

Given the serious plight of their economies, East European countries and the Soviet Union have accepted the concept of western market economics, officially accepting the closing document of the first economic conference organized by the 35-nation Conference on Security and Cooperation in Europe (CSCE) in Bonn last month.

The document—which is not legally binding but carries moral weight similar to the CSCE human rights document of Helsinki in 1975—commits the nations to "endeavor to achieve" the following: free and competitive market economies where prices are based on supply and demand; fiscal and monetary policies that promote economic growth and enhance the ability of markets to function efficiently; policies aimed at expanding the free flow of trade, capital, and investment; and the repatriation of profits in convertible currencies.

Jay Mitchell, manager of the Sovi-

Warsaw
Lodz
Kraków

Poland in brief

Size: 120,727 square miles

Population (1988): 37.9 million

GNP (1988): $276 billion

GNP per capita (1988): $7271

World trade:

- **Imports (1988):** $12.2 billion
- **Exports (1988):** $14.0 billion
- **Telephones per 100 people (1985):** 12
- **Automobiles registered per 1000 people (1986):** 105

Largest of the East European countries in population and area, Poland is also the richest agricultural country of the region because of its flat, lowland character. It also is rich in mineral resources, such as coal, lignite, sulfur, zinc, lead, and copper, and is highly industrialized as well.

Important industries include shipbuilding, chemicals, metals, motor vehicles, and food processing. Grain, potatoes, sugar beets, and oil seeds are grown in quantity, and livestock also are important. Chief imports include machinery, fuels, and raw materials. Machinery and equipment, coal, steel, and food products are significant exports.

Historically, Poland has been the chief U.S. trading partner in East Europe, but this relationship was hurt seriously following the crackdown on Solidarity in 1981. But most-favored-nation tariff status was renewed by the U.S. in 1987 and recently the government has taken other steps toward economic monetary reform to make foreign investment more attractive. However, most of the 70-odd investments by U.S. firms there remain relatively small.

et and East European Chemical Service, for PlanEcon, said at the recent London conference that in East Europe, "the trend will be different from Soviet joint ventures—the ventures will be small scale." They also will be focused more on specialty products in such areas as pharmaceuticals, synthetic fibers, paints, herbicides and fungicides, and specialty plastics. "The emphasis will be on specific downstream projects," he adds.

In the Soviet Union, free-market companies have been invited to bid on petrochemical megaprojects—on the $2 billion project in Tobolsk, western Siberia, with partners including Neste and Hyundai of South Korea; or Shevchenko, about which Dow has submitted a feasibility study which the Soviets are now studying.

In East Europe, however, the projects thus far in the chemical industry have been smaller and more marketing oriented, with a few selected manufacturing ventures. For example, Glaxo Eastern Europe, established to manage and develop the business of Glaxo, the British pharmaceuticals maker, has medical and trade links in Poland, and manufacturing cooperative agreements there for two of its injectable cephalosporin antibiotics. In Hungary, it has a local manufacturing agreement for ranitidine and clobetasol, and has an office in Budapest.

A joint venture by Dutch chemical company Akzo in Hungary is typical of the new breed of venture. Akzo's venture with Tiszai Vegyi Kombinat will produce coatings in Leninvaros. Akzo will have a 51% interest; the plant will begin production by the middle of this year. It will supply the Hungarian market with a full range of coatings and finishes, including resins, with an emphasis on coatings for industrial applications and for the auto industry.

"This is not a small thing," says Willem E. Kulsdom, director for geographical coordination at Akzo. "It fits well with our strategy, and meets the yardsticks of finance and support of our core business units—but also, the project is interesting for both sides. It provides Hungary an opportunity to buy products locally with Akzo technology, to add value to their manufactured products for exports. These will be indirect exports for us. We are giving added value."

And Dow Chemical is building a new plant in Hungary, also, in a $14 million to $15 million joint venture with Nitrokema and Chemolimpex, agreed upon in June 1989, in which Dow has a 50% interest. According to René Wildi, Dow Europe vice president, the plant will produce the company's Styrofoam—extruded polystyrene for foam insulation. "Construction is now under way, and we expect it to go on stream, as scheduled, in early 1991," he says. "It is on time, and on budget—that is very important, particularly when you talk about your first such investment."

In part, western chemical companies have to be alert to investment opportunities that open up—or work to make them open up, if only to follow their customers. As western automakers flock into major joint ventures with their East European counterparts, for example, suppliers of coatings, parts, lubricants, and the like must be there as well. Even when they have already been there, they must be prepared to meet new market needs. For example, auto coatings producers like the U.S.'s PPG Industries and Herberts, the paint subsidiary of Hoechst, have begun demonstrating their fashion coatings line to eastern automakers, who, before, had clung dourly to the notion of drab, solid colors.

On the other hand, ventures have not been all one way. In February, Dyno Industries, the Norwegian chemicals and explosives company, and AHB Chemie, the East German chemicals trading company, formed a 50-50 joint venture to make formaldehyde resin in Gent, Belgium, to supply the particle board industry. The new plant, due on stream by mid-1991, will replace deliveries from a Dyno plant in the Netherlands that is scheduled to be closed next year and from Leuna Werk, AHB's plant in East Germany.

According to Dow's Wildi, one of the major changes expected—a wholesale shift away from centralized buying in East Europe—still is to come.

"In most countries, there are reported to be changes in the approach to running the chemical industry, but they have not happened yet, maybe with the exception of East Germany," he says. "The decentralization, if it comes, will create tremendous problems for us, and our customers as well. Among the difficulties: ensuring that there is a common commercial language.

"If you go back to the U.S.S.R., they said two years ago that the foreign trade organizations would be eliminated. But now, more than 90% of the business still is being handled by these organizations."

A West German chemical executive identifies a major, positive shift. "In the past, you could only work with the ministries or foreign trade organizations. You had no opportunity to come together with the plant people, unless there was a big technical problem, for example. They felt it was not necessary to get together on the sales side. Sometimes, it was done anonymously—but at risk. Now it is much different."

It is still worth the patience, however, contends Akzo's Kulsdom, to tap into the reservoir of trade expertise. "We should realize that in East Europe, there is a huge experience in trade between Comecon partners. A huge marketing knowledge, although not in our terms or our understanding of marketing—knowledge of existing conditions, and existing demand. People may change, but the expertise is there."

Selling in East Europe, most chemical companies agree, is best done with the company's own sales staff. As Marc G. Schriber, Du Pont International's director for East Europe, puts it, "Sales representatives have trouble investing two or three years in an industry. They have to have commissions in each month. But to us, the two or three years is our daily bread. To develop long-term, we must do it ourselves. We can train our people much better."

Whoever does the selling or market development work, however, has quite a job, Schriber adds. "It takes a lot of skills to serve a customer in the East. For example, first, you have to find out who the customer is. There is no switchboard, there are no telephone directories. A lot of

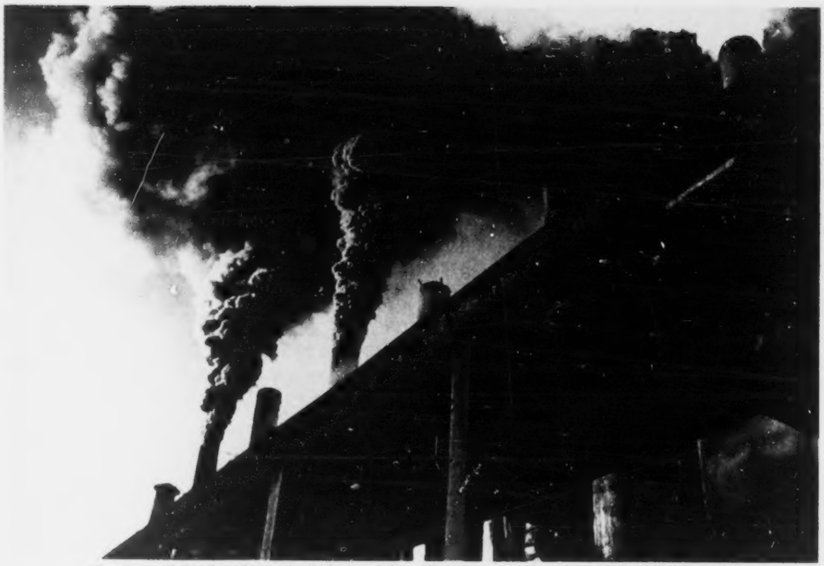


Photo by Black Star's Andrew Holbrooke

Carbon black plant belches air pollution at Copsa Mica, Romania

knowledge on how to do business—trivial but crucial—can be picked up only over many years' experience."

Direct product selling is one thing; selling licenses or setting up joint ventures is another, for a particularly important reason for the chemical industry: intellectual property rights and patents. So far, however, it is a topic not satisfactorily addressed by the governments of any of the East European countries.

Says one industry executive, "Intellectual property is a field not touched yet. We used to complain about it, in the past. They are well aware that a market economy—which they all want to have—must have protection of intellectual property. But they have not really touched the problem yet. They are too busy working on things like convertibility of currency, and full employment. They will have to touch on it, though, because investors will ask them."

Photo by C&EN's Ward Worthy

A major Romanian plant for fertilizer is at Turnu-Măgurele, on the Danube

Environmental problems are frustrating for western companies, industry officials agree. Technology that now exists to clean up pollution problems often is too expensive to be afforded—or local bureaucrats find it impossible to make the ultimate decisions to go for cleanup. And a rising green movement within East Europe is having its effect: Although there are clean technologies in the chemical industry, some analysts believe, the East Europeans have been so traumatized over the past 40 years that no technology can be clean enough for them to accept.

Until six months ago, the issue really was only Russia—perestroika and glasnost and their impact on the global balance of power or the nuclear arms race, according to Martin J. Kallen, corporate vice president of Monsanto and chairman and managing director of Monsanto Europe. Things are much more complex now, he agrees, but he believes the U.S.S.R. is still the key, a magnifying mirror for conditions elsewhere through East Europe.

The Soviet Union, of course, has its own problems in the size of its country. But other East European countries share a diversity in people and climate, ethnic problems, drought problems and wind-driven soil erosion in agriculture, inadequate infrastructure, the poor health of the people, declining life expectancy, the drabness of life, and instant antiquity—"a plant built two years ago looks 40 years old," Kallen said, at a recent speech to the American Club in Brussels.

How each country restructures its industries and their links with research institutes will probably go a long way toward helping solve that problem. For Hungary and Poland, the answer is to get the industry privatized, even if that means into foreigners' hands. At least one executive has predicted that within 10 years, for example, much more than half of Hungary's chemical industry will have non-Hungarian ownership.

And the Polish Minister for Industry said recently, when meeting with a British trade delegation, "In Poland, 99.9% of the property is owned by the state, and somebody has to sell it," reports John C. Mitchell, head of East European affairs for ICI.

There are serious and significant problems facing investors contemplating investing in East Europe, says Mitchell. But, as he told the Commercial Development Association in New York earlier this year, "It is no longer an option to omit consideration of the U.S.S.R. and East Europe from global business or product strategies. The days when that option was available have disappeared under the avalanche of change and exposure to which part of the world is now being subjected."

It's not really a revolution that the region is going through, Mitchell adds, but a "long-term transition only now started. The question is, is the chasm leapable? You can't leap a chasm in two leaps. What you have in Eastern Europe is chaos, accelerating chaos."

With the long-term orientation needed for East European investment, companies believe they can afford to be cautious in the short term. "What happens over the next four to five years will be interesting but not terribly large," predicts H. M. Rowson, director at Trichem Consultants Ltd., in London. "There won't be big money going into the East bloc until people think the politics are more secure.

A report from the United Nations Economic Commission for Europe, published last month, says East Europe cannot absorb large amounts of foreign financial aid, partly because the necessary physical and institutional infrastructure is lacking. The Marshall Plan package of mostly grant aid with a small proportion of technical assistance "should be turned on its head," the report says.

Another report, however, from four leading European economic research institutes—Cambridge Econometrics, BIPE of Paris, Prometia of Bologna, and IFO-Institut of Munich—said last month that East Europe's switch from communism to capitalism will enlarge the region's need for imports. In fact, the report said, EC exports to East Europe will become more important than exports to North America by the end of the century.

Even with a loose trading organization such as CMEA or with trade agreements, there has been duplication of effort, notes Terry F. W. Baker, a principal with Chem Systems Ltd., in London. "Eastern Europe is the fourth-largest petrochemical producing area, but all the companies there have aimed at self-sufficiency."

Metz: reforms in the East have brought Europe closer together

Kulsdom: joint venture in Hungary fits well with firm's strategy

Wildi: no wholesale shift from centralized buying in the East yet

Two years ago, Chem Systems began a major multiclient study, "East European Petrochemicals: Impact on the West," which it finished last July. Among the major conclusions of the study is the unsurprising fact that plants don't run at capacity, but rather probably at only about 80% of capacity. "They have the potential to produce more at their existing plants, but they don't have the feedstocks," Baker says. Moreover, because the various ministries have paid for the plant, there is no element of capital costs—no capital return concept. "The incentives have been in terms of maximizing volume, not quality, and there has been no incentive to improve quality of factories."

However, the region is set to grow, and grow fast, Baker believes. "This is a population with expectations: They are Europeans, and they want a comparable standard of living to West Europe. They don't want things just a bit better than before, they want the freedoms of West Europe, the goods of West Europe. Look at West Europe at the end of the war—and then look at it 20 years after the war. East Europe, given the same sort of aid and incentives, could achieve the same sort of growth and recovery. It may have to pull down polluting factories—but is that worse than if they had been bombed and had to be rebuilt from scratch?"

Baker and Chemicon Surveys' Cox point out one of the fundamental problems with the industry in East Europe: its size, or—more precisely—lack of size.

Individually, each country is rather small. Says Baker, "To be an effective economic block, these countries will have to get together some way—a trade network, perhaps—something to sustain a whole range of industries, to give a critical mass, to sustain industry at a West European standard of living. We figure, for example, it takes about 10 million people to sustain an ethylene cracker."

So the question has to be asked: Is there a need for a chemical industry in each country? According to Cox, the existence of a basic chemical industry in each country is a relic of Stalinist economic planning, such that each country should have its own petrochemical industry, its own steel industry, its own whatever. However, if one starts looking at each country as a separate unit, there are few with the significant indigenous resources to support a basic chemical industry and few with a large enough domestic market.

It is not outside the bounds of reason that, eventually, the states will decide to encourage resources spent on more profitable, high-value added parts of the industry, and to shift away from basic chemicals. A possible role model: Ireland, which has encouraged a specialization in pharmaceuticals.

The problem facing the industry in East Europe is simple: It must justify its existence. It must justify why companies should include the region in their strategic investment planning, most of which is worked out for three to five years in advance.

It must particularly justify itself as a candidate for investment funds in competition with other areas that have more immediate promise, with less remedial work: areas such as Spain and Portugal or Southeast Asia, all of which are figuring high on corporate investment plans.

East European countries will find themselves facing the need to put together packages of incentives to attract companies to build there. Points out Chem Systems' Baker, "There still will be competition between countries to get better investment terms—even somewhat more so than the way states or regions compete in the U.S. The stimulus will come from investment and outside expertise—to build factories and run them, to get things going."

Adds Akzo's Kulsdom: "There must be a prospect for reasonable profit and return in [the] foreseeable future. No company would be satisfied with not getting profits for 10 years. Most of our strategic investment planning is over a period of about about three to five years. Perhaps there will be some other considerations for East Europe, but there won't be a completely different yardstick. Any activity should bring a reasonable profit, including any investment in East Europe."

Prague
Brno
Bratislava

Czechoslovakia in brief

Size: 49,365 square miles

Population (1989): 15.7 million

GNP (1988): $158.2 million

GNP per capita: $10,130

World trade:

- **Imports (1988):** $24.2 billion
- **Exports (1988):** $24.9 billion
- **Telephones per 100 people (1985):** 23
- **Automobiles registered per 1000 people (1986):** 173

Czechoslovakia is a federation of the Czech (Bohemia and Moravia) and Slovak republics whose location in the heart of Europe has led it to play a significant economic, political, and cultural role in the continent's history. About two thirds of its citizens are Czech. Although not rich in natural resources other than coal, the country has one of the most advanced economies in East Europe and is highly industrialized.

Machinery, steel, glass, chemicals, cement, motor vehicles, and military equipment are important products. Major imports include machinery, raw materials, and consumer goods. Leading exports include machinery, steel, glassware, and chemicals.

Long-strained relations with the U.S., stemming from Czechoslovakia's hardline communist policy now have eased markedly. Legislation permitting foreign investment was passed for the first time in 1987, but little had been done to encourage such investment while the communist government was in control.

U.S. chemical firms look eastward

If business officials in West Europe are still uncertain about their role in East Europe, their colleagues in the U.S. are even more so of two minds about prospects there.

"Political and economic reform in East Europe is transforming one of the most stagnant areas of the world into one of mind-boggling opportunities," says Carla A. Hills, the U.S. Trade Representative. On the other hand, Paul McGonagle, a senior vice president of the First National Bank of Chicago, warns, "Political and economic reform (in East Europe) cannot be predicted. The perceived risk has increased."

Hills and McGonagle could both be right. The political and economic upheaval that has swept East Europe could, indeed, present U.S. companies with mind-boggling business opportunities. But there is no doubt that those opportunities come attached to a high degree of risk.

As a result, the euphoria that blossomed from East Europe's initial leap out of rigid, socialist regimes into a free, market-based society has been replaced with caution. Indeed, U.S. business executives, including those in the chemical industry, use the word "caution" much more often than "unbounded opportunities" in describing how they feel about U.S. business potential in East Europe.

The other key word in discussing business opportunities in East Europe is "patience." Only the naive expect to make quick profits there.

Richard M. Patterson, government relations manager for Dow Chemical U.S.A., noting the lack of resources in East Europe and the depressed state of the economies there, asks, in fact, where are the opportunities? He concedes that there is consumer demand. But he wonders if income levels are there to make the purchases.

If gross domestic product goes up and things don't collapse first, says

Patterson, eventually there will be markets in East Europe for western companies to satisfy. Take a snapshot of business opportunities there today, and it is not a pretty picture, he says. Take it five years from now, and the picture will look better. Take it 10 years from now, says Patterson, and that picture could look positively attractive.

Max L. Turnipseed, Ethyl's manager of international affairs and special trade adviser for the Chemical Manufacturers Association, believes that there are opportunities for U.S. chemical companies in East Europe. But, he says, it will be a long time before U.S. companies feel comfortable pursuing them.

"There's always a political risk there," says Turnipseed, "but the rewards can be high if you're willing to take the risk." And he quickly adds that if U.S. companies don't take that risk, "our European and Japanese friends will."

Jay K. Mitchell, manager of Soviet & East European Chemical Services at PlanEcon, agrees that European companies probably have a leg up on U.S. companies in East European business dealings. And he agrees that Japanese companies have their eye on opportunities in East Europe.

Japanese companies, he points out, are heavily invested in West Europe's industrialized countries, and they are already moving into East Europe. They have one big trump card, says Mitchell, and that is money. They also have patience.

There's still a lot of uncertainty about East Europe that makes weighing risk against opportunity difficult. Geza Feketekuty, a former counsel to the U.S. Trade Representative, says that no one really knows what is going to happen. "We are fairly sure of the direction of change [in East Europe]," he says, "but the pace and precise nature of the change is unclear."

It's a safe bet that most of the East European countries will emerge from their transition process near bankruptcy and heavily in debt. Despite the progress, political vacuums still exist in some countries. Everyone agrees that East Europeans will need "things," but wonder where they will get the money to pay for them.

Schriber: a lot of skills are needed to serve customers in the East

The problems seem endless. Nevertheless, Feketekuty believes that investing in and trading with East European countries will be worth the risk. Like many others, he points out that U.S. companies can enter those markets now at high risk, but with big payoffs. Or they can wait until the political and economic dust settles. Then, the risk will be lower, but so will the payoff.

Peter Orenski, president of TME Co., a consulting company in New Milford, Conn., is much more optimistic about East Europe than he is about the Soviet Union. Orenski, a former Union Carbide employee who founded TME, describes himself as "Dr. Death" when it comes to advising his clients about doing business in the Soviet Union.

He tells them that unless they have a strategy that stretches to the 21st century and deep pockets, go to the U.S.S.R. only as a tourist. "Otherwise, you'll lose your shirt," he says.

He believes that East Europe is a different story. Countries there, he says, are less likely to be concerned with dumping communism than the Soviets are. In East Europe, communism was an unwelcome intruder.

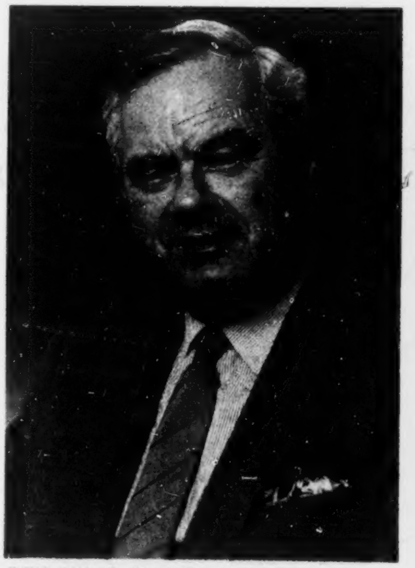
What distinguishes East Europe from the Soviet Union, says Orenski, is that the East Europeans have what he calls "a social contract" to shed communism and rejoin the world of democracy and market economies. As Orenski sees it, East Europeans are saying to each other, "Let's suffer together for five years or so through this transition so that we can have a better future."

Social contract or no social contract, the transition will be a difficult and painful task. East European countries will need financial help from the West, both from public and private sources.

Indeed, money from the West already has started flowing into East European countries. Western governments are providing financial aid directly, through international lending agencies, such as the World Bank, and to private organizations to encourage trade with or investment in East Europe.

One of the U.S. government's major aid efforts was launched last year when Congress passed the so-called SEED Act (Support for East Europe Democracy). The SEED Act authorizes a three-year, $928 million assistance program specifically for—and only for—Poland and Hungary. Before the funds become available, Congress must appropriate them each year. For fiscal 1990, Congress has already appropriated $536 million.

The SEED Act is a wide-ranging



ICI's Mitchell: in East Europe, accelerating chaos piece of legislation, with 25 distinct provisions falling into six broad categories. Several different government agencies are responsible for handling the money, but most of the funding is handled by the Agency for International Development (AID).

Funds are provided for "structural adjustment," private-sector development; trade and investment; educational, cultural, and scientific activities; and other assistance programs. One of the most important is private-sector development. The SEED Act authorizes $240 million for a newly established Polish-American Enterprise Fund and $60 million for a Hungarian-American Enterprise Fund.

For fiscal 1990, $45 million and $5 million have been appropriated for the Polish and Hungarian funds, respectively. Although these funds, which are private, nonprofit organizations, will receive the money from AID, a board of directors governs the funds themselves. The board of directors includes private citizens from both the U.S. and the host country. The organizations will use the money to provide loans, equity investment, feasibility studies, technical assistance, and training to private-sector groups in Poland and Hungary.

Although the SEED Act provides funds only for Poland and Hungary, some Congressmen and Administration officials are considering a SEED Act II, which would extend financial aid to other East European countries.

U.S. financial aid, however, comes in different shapes and sizes. Direct authorized assistance that the SEED Act provides is only one of them. The U.S. also makes contributions to international lending agencies such as the World Bank, the International Finance Corp., and the International Monetary Fund.

The Administration is drawing fire, however, over its proposal to participate in a new European Bank for Reconstruction & Development. The bank is set up as a regional development bank for East Europe and the U.S.S.R. But opponents in the U.S. complain about Soviet participation. They fear that the Soviets will divert resources from the bank that they would prefer to see going to the fledgling democracies in East Europe.

Most of East Europe's chemical trade is with other European countries

World chemical trade, $ millions	Exports to World	East Europe	U.S.S.R.	U.S.	West Europe	Japan
EXPORTS FROM						
World						
1980	140,748	4513	4877	7,895	71,318	5346
1985	152,111	5299	4893	13,382	71,431	6804
1987	214,814	7038	6195	16,047	109,230	9750
East Europe						
1980	6,013	1178	1703	51	1,698	52
1985	7,979	1355	2127	146	1,958	72
1987	9,283	1715	2779	159	2,098	88
U.S.S.R.						
1980	1,704	614	—	116	505	5
1985	2,772	1033	—	195	632	60
1987	2,945	1422	—	136[a]	534	50
U.S.						
1980	20,728	58	31	—	6,230	1972
1985	21,255	87	282	—	6,375	2849
1987	25,631	79	264	—	7,525	3366
1988	31,343	68	268	—	8,778	3937
West Europe						
1980	90,288	3455	2528	3,845	58,716	1778
1985	91,671	2307	1702	6,575	57,647	2341
1987	137,844	3157	2310	8,332	92,127	4311
1988	158,211	3308	2352	9,895	105,712	5088
Japan						
1980	6,619	90	322	769	876	—
1985	7,542	67	256	1,404	1,111	—
1987	11,545	95	329	2,086	1,978	—
1988	13,904	93	357	2,303	2,520	—

Note: Does not include trade between East and West Germany. Some East Europe and U.S.S.R. data may be suspect because of problems in converting from nonconvertible currencies to dollars. **a** 1986. **Source:** United Nations

Meanwhile, other U.S. government agencies are involved in lending to or insuring U.S. business with East European countries. One of them is the Overseas Private Investment Corp. (OPIC), an independent government agency. OPIC assists U.S. investors by making direct loans and/or loan guarantees to finance investment projects overseas and insures foreign investments against a wide range of political risks.

Another is the Export-Import Bank (Eximbank), which finances export sales of U.S. firms. Eximbank recently extended short-term credit insurance to cover U.S. exports to Poland and opened all of its programs to U.S. exports to Czechoslovakia. Meanwhile, Congress is considering a bill that would permit Eximbank to extend medium-term, as well as short-term, direct loans to public and private enterprises in Poland that want to buy U.S. goods.

John D. Macomber, chairman of Eximbank, says it and its counterpart export credit agencies in other industrialized countries are a significant source of capital for developing countries, including countries in East Europe. The World Bank has $250 billion outstanding in loans. Less well known is that western countries' export credit agencies collectively have $220 billion outstanding. About $16 billion of this is in the six East European countries.

There is a lot of money available to help companies from the U.S. and other western countries who want to start doing business in East Europe. Deputy Secretary of State Lawrence S. Eagleburger, who is coordinating U.S. assistance efforts, estimates that as a ballpark figure, "about $10 to $15 billion of multilat-

Communist countries face a big challenge in putting their chemical industries into private hands

Sales (1989), $ billions	State-owned companies	Privately owned companies	Publicly owned companies	Joint ventures with foreign companies	Total
Communist countries	$85	—	—	$20	$105
West Europe	50	$50	$205	—	305
U.S. & Canada	—	30	210	—	240
Japan	—	30	50	55	135
Middle East, India & Africa	20	15	10	10	55
Latin America	23	5	10	2	40
Southeast Asia & Australia	15	5	10	10	40

Source: Shell

eral aid will probably flow into East Europe over the next few years in the form of direct assistance, investment, and possible debt restructuring. Of this, $1.2 billion would be overall assistance from the U.S."

The Administration has other irons in the East European fire besides financial aid. It has been busy negotiating trade and investment agreements with several East European countries, agreements that should benefit U.S. companies. And it has been "conditionally" supporting some East European countries' attempts to join such global organizations as the General Agreement on Tariffs & Trade and the International Monetary Fund.

U.S. trade and investment policy toward East Europe is coordinated by the interagency Trade Policy Review Group, which is chaired by the U.S. Trade Representative. Peter Allgeier, assistant USTR, says the goal is simply to establish normal economic relations with East European countries. Exactly how the U.S. does this depends upon how fast and how far these countries go in setting free elections, establishing a market-based economy, and respecting human rights.

It also depends on whether the U.S. already grants an East European country most-favored-nation (MFN) tariff treatment. MFN is the cornerstone of most trade in the western world. Basically, it means that tariff concessions granted to one country will be granted to all MFN countries. Exports from countries that do not enjoy MFN treatment usually carry much higher tariffs. Obviously, any country, East European countries included, would welcome MFN treatment for its exports.

Under Title IV of the 1974 Trade Act (the "Jackson-Vanik" amendment), MFN is denied to countries that have restrictive emigration policies. And before the U.S. can grant MFN to Czechoslovakia, East Germany, and Bulgaria (and the Soviet Union,) it must negotiate "Title IV" commercial agreements with these countries.

Last month, the U.S. and Czechoslovakia signed such an agreement. But even with Title IV agreements, the U.S. must withdraw MFN treatment if a country's emigration policies become restrictive.

West Germany dominates the European Community's chemical trade with East Europe

	Imports of chemicals to EC, 1987		Exports of chemicals from EC, 1987	
	Leading importer	Value to that country, $ millions	Leading exporter	Value from that country, $ millions
Bulgaria	Greece	$ 3.5	Italy	$18.2
Czechoslovakia	West Germany	22.5	West Germany	26.7
East Germany[a]	Italy	22.7	Netherlands	9.3
Hungary	West Germany	11.1	West Germany	23.4
Poland	West Germany	33.2	Ireland	31.5
Romania	Italy	9.0	West Germany	22.9

a Excludes trade with West Germany. Source: European Community

That would leave Bulgaria and East Germany still without MFN privileges. Bulgarian and U.S. trade officials have met to discuss the possibility of a Title IV agreement. But these discussions are very preliminary. The State Department is still reviewing Bulgaria's emigration situation to see if the country merits a waiver of the Jackson-Vanik amendment.

The U.S. hasn't held trade agreement talks with East Germany. It, along with the rest of the world, is waiting to see what happens about reunifying the two Germanys. Believing that this could happen soon, Allgeier says the U.S. probably will not seek a separate trade agreement with East Germany.

Poland and Hungary already enjoy MFN status with the U.S. Romania had been granted MFN status, but the Ceauşescu regime renounced it in 1988 after the U.S. criticized its human rights performance.

Poland also benefits from the Generalized System of Preferences (GSP), which allows a country's exports to enter the U.S. duty-free if the country and product meet certain conditions. Poland doesn't require a Title IV agreement because of its MFN status, but President Bush and Prime Minister Tadeusz Mazowiechki signed a comprehensive "business and economic" treaty in March.

U.S. trade officials also have talked with Hungary about a similar agreement. Like Poland, Hungary has MFN and GSP from the U.S. But, unlike Poland, Hungary is subject to the Jackson-Vanik amendment.

Despite these trade agreements, the U.S. can't completely normalize its trade relations with East European countries so long as the Jackson-Vanik amendment slaps conditions on how the U.S. grants MFN status. GATT requires unconditional MFN treatment, which the U.S. can't promise.

Hungary, Czechoslovakia, and Romania are members of GATT. So, too, is Poland, but Jackson-Vanik restrictions don't apply to Poland. The conflict between GATT rules and Jackson-Vanik requirements complicates U.S. international trade relations. Bulgaria has been a GATT observer since 1967 and has applied for membership.

Despite all the government aid and actions, by the U.S. and other western countries, the widely held opinion is that private western investment in East Europe will be more important in ensuring a complete transition to market economies.

But private groups will be cautious about committing funds to East Europe. For instance, the Institute of International Finance recently warned that East Europe shouldn't expect international commercial banks to take the lead in financing its economic reforms.

The institute says that banks will be cautious about making long-term loans to government-owned enterprises in East Europe. They are afraid that they may get hit with the large losses they suffered in lending to Latin American countries.

For manufacturing companies, including chemical companies, the most likely route to investment in East Europe will be through joint ventures.

Dow's Patterson says, for instance, that its joint-venture investment in Hungary, to make polystyrene foam insulation products, makes sense because the investment climate there is favorable. There is also a big demand for foam insulation in the Hungarian building and construction industry. To develop the market, Dow has been exporting the product to Hungary to acquaint architects and builders with the material.

According to a recent Department of Commerce tabulation, U.S. companies have 216 joint ventures in East Europe, with more than half of them in Hungary. But that number pales beside the almost 2000 joint ventures that have been formed in East Europe by all western companies.

PlanEcon's Mitchell, however, believes that U.S. chemical companies can be competitive in forming joint ventures in East Europe. And he believes that they are doing a better job than U.S. companies in other segments of manufacturing.

But it isn't easy. Ethyl Corp.'s Turnipseed says that his company worked for years to form a joint venture in Czechoslovakia, but finally gave up when it realized that there were too many obstacles. He declines to say what the joint venture would have produced. From a marketing and technical viewpoint, says Turnipseed, the project looked fine. But "the uncertainty did it in," he says.

John R. Dearborn and Richard M. Sol agree that establishing joint ventures in East Europe is difficult. The two have had extensive East European and Soviet dealings as licensing manager and director of licensing sales, respectively, for Union Carbide's Unipol Systems Department. Says Dearborn, "The more I learn, the more questions I have."

Dearborn says the major changes occurring in East European countries make matters even more confusing. Power is being transferred out of ministries into production centers, which makes it difficult to know who is in charge of what.

Sol repeats the warning that negotiating joint ventures in East Europe takes a lot of time and effort. "Don't expect to sign a deal in two weeks," he says.

Dearborn agrees. He says that, when he was in the Soviet Union, it was a year before he fully understood how to go about business there. The situation is not much different in East Europe.

Carbide has sold Unipol polyethylene and polypropylene plants in the Soviet Union, as well as polyethylene units in East Germany and Czechoslovakia. It is now negotiating with Poland and East Germany for additional units.

Sol says that there may be potential for U.S. chemical companies to establish joint ventures in East Europe, but warns them that it will be a long-term commitment. "Many have tried the fast track and failed," he says.

Hungary in brief

Size: 35,919 square miles

Population (1987): 10.6 million

GNP (1988): $87.5 billion

GNP per capita (1988): $8178

World trade:

- **Imports (1988):** $4.32 billion
- **Exports (1988):** $5.40 billion
- **Telephones per 100 people (1985):** 14
- **Automobiles registered per 1000 people (1986):** 145

Hungary is a mountain-rimmed country dominated by a great fertile plain and bisected by the Danube River. It has a mixed agrarian-industrial economy but relatively few mineral resources.

Steel, machinery, pharmaceuticals, motor vehicles, communications equipment, food processing, and distilling are major industries. Grain, vegetables, fruits, and grapes are leading crops and livestock are also a significant agricultural product. Hungary's leading exports include machinery, transportation equipment, consumer goods, and agricultural products. Major imports are raw materials, fuels, and machinery.

Hungary has been in the forefront—since 1968—in economic reform now taking place in East Europe. It launched the region's first aggressive program of privatization in 1989, and also has taken the lead in liberalizing foreign investment rules and building trade relations with the European Community and other western countries. More than 100 U.S. companies have established joint ventures or subsidiaries in Hungary, and the pace of foreign investment has continued to quicken.

Poland is biggest East European customer for U.S. chemicals

$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980
Bulgaria									
U.S. chemical exports	$ 5.9	$ 9.3	$ 10.6	$ 9.1	$ 16.2	$ 13.3	$ 13.9	$ 36.5	$ 12.2
U.S. chemical imports	9.9	5.8	3.5	4.5	3.5	1.2	1.5	0.9	0.5
Balance of chemical trade	−4.0	3.5	7.1	4.6	12.7	12.1	12.4	35.6	11.7
Czechoslovakia									
U.S. chemical exports	3.8	9.0	19.4	23.4	16.5	17.7	2.1	2.2	3.7
U.S. chemical imports	2.5	2.4	2.0	1.2	1.4	3.0	4.1	1.5	1.5
Balance of chemical trade	1.3	6.6	17.4	22.2	15.1	14.7	2.0	0.7	2.2
East Germany									
U.S. chemical exports	2.3	2.9	2.1	1.0	3.2	1.5	1.2	3.2	8.8
U.S. chemical imports	27.1	18.3	27.3	8.7	17.5	9.8	6.2	5.1	4.7
Balance of chemical trade	−24.8	−15.4	−25.2	−7.7	−14.3	−8.3	−5.0	−1.9	4.1
Hungary									
U.S. chemical exports	18.4	18.7	12.7	11.9	12.7	9.7	14.6	15.9	9.2
U.S. chemical imports	21.6	26.8	28.4	21.7	11.7	10.7	6.4	7.3	5.9
Balance of chemical trade	−3.2	−8.1	−15.7	−9.8	1.0	−1.0	8.2	8.6	3.3
Poland									
U.S. chemical exports	32.4	29.2	29.5	30.4	7.5	10.1	32.2	12.1	16.9
U.S. chemical imports	29.0	11.1	6.7	4.7	4.6	5.6	8.6	15.3	22.6
Balance of chemical trade	3.4	18.1	22.8	25.7	2.9	4.5	23.6	−3.2	−5.7
Romania									
U.S. chemical exports	5.8	10.7	22.7	10.9	10.8	13.9	14.0	5.5	5.5
U.S. chemical imports	11.8	6.8	95.1	141.6	78.0	22.6	6.3	6.8	10.3
Balance of chemical trade	−6.0	3.9	−72.4	−130.7	−67.2	−8.7	7.7	−1.3	−4.8

Source: Bureau of the Census

PlanEcon's Mitchell expects the number of East-West joint ventures in East Europe's chemical industry to increase. Right now, he says, European companies seem to have the edge. But he insists that U.S. companies can, and are, making inroads.

East Europe a mixture of weaknesses and strengths

Whether it's a government handout, private financing, or investment through joint ventures, there's little doubt that these countries can use all the aid they can get—probably more than they will get from the West. They must endure the trauma of converting from their old socialist system to a market-oriented system. And they must do it while starting from an industrial base that has been beaten into the ground after 40 years of communist rule.

In East Europe some countries are in worse shape than others. As a result, TME's Orenski has what he calls a "worry list" and a "positive list." The Soviet Union heads his worry list, but Bulgaria and Romania also are well-entrenched on it.

He characterizes Bulgaria as a big unknown—"a mystery wrapped in an enigma." Bulgaria has been called worse things—the backwater of East Europe, for instance.

Prospects for reform in Bulgaria are not so bright as in other East European countries. It is the least developed of those countries. And European-style political and economic traditions are missing.

Bulgaria doesn't have the strong ties with the West that other East European countries, such as East Germany and Czechoslovakia, have. And whereas Hungary has neighboring Austria to hold its economic hand, Bulgaria has no such partner.

Communists still rule in Bulgaria. But, relatively unnoticed, Bulgaria has enacted some major economic reforms in the past two years. These reforms include legal rights for private enterprise and a foreign investment law that provides for 100% foreign ownership.

Bulgaria is a relatively minor chemical producer in East Europe. That chemical stature shouldn't change much in the near future. Its small population doesn't trigger much chemical demand. Its chemical industry is outdated and dilapidated. Production of many chemicals has been declining since 1985, particularly polyvinyl chloride since the Devnia PVC plant was destroyed accidentally in 1986.

Recently, Bulgaria's chemical exports have been running about 3% of total exports, which is a very small share. Its chemical exports to the industrialized West have been the smallest of any East European country by far. In fact, Bulgaria ran a chemical balance of trade deficit of $372 million with the industrialized West in 1987.

Like Bulgaria, Romania still hasn't decided exactly what to do about a free market future. Its political situation still is in flux and there is no clear political leader. Dow's Patterson calls Romania "a disaster." He adds, "It will be a long time before it gets its act together."

Debtwise, Romania is in good shape to borrow. But it will need massive amounts of money to restore its crippled economy. What's more, Romania's reputation has been tarnished. There's a limit to the aid that the West can provide to East Europe, and Romania may be at the back of the line.

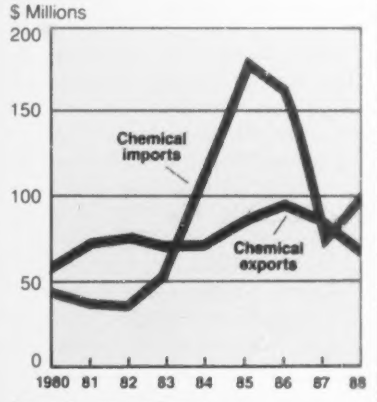
Chemical production statistics are scarce for Romania. What there is probably overstates production and production growth rates. Nevertheless, the data show that the chemical industry has grown even more slowly than other major industrial sectors. In fact, output of practically all chemicals has dropped since 1985. "Output has probably fared even worse for the chemicals not reported," says PlanEcon's Mitchell.

Mitchell says Romania has fewer chemical plants being supplied their raw materials by western firms than any other East European country. To him, that's a sure sign that Romania's chemical industry is falling even further behind those of its East European neighbors.

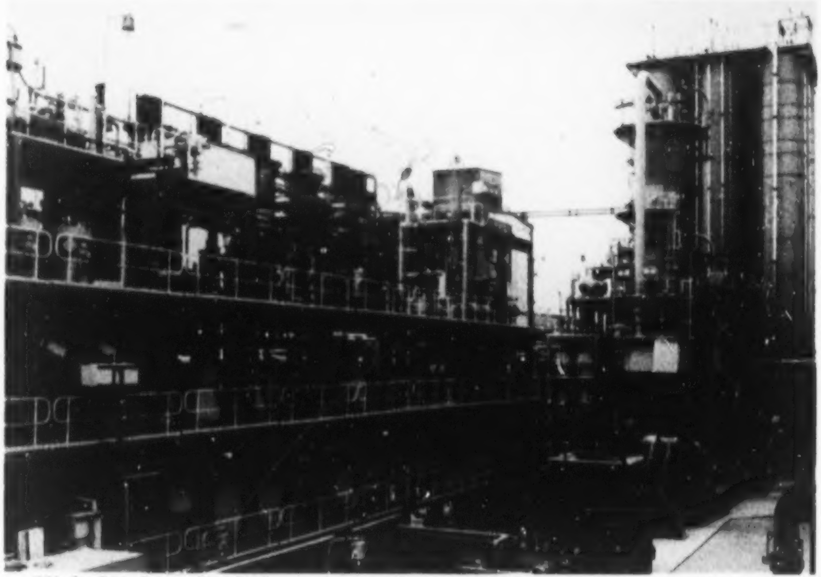
Now that Romania's hard-currency debt has been repaid, Mitchell believes that the country's chemical industry may be able to attract at least some of the large amounts of funds that it desperately needs to modernize and expand. But many westerners are still wary of Romania. It may be years before Romania will be able to offer attractive lures to investors.

Orenski calls Romania a "wild card." It has had a checkered past with no guarantee that it can make it on its own. Of the six East European countries, he believes Romania is the riskiest bet.

U.S. has had a deficit in East European chemical trade



Source: Bureau of the Census



High-density polyethylene plant is licensed to use Carbide's Unipol process

On Orenski's "positive list" are Poland, East Germany, Czechoslovakia, and Hungary. Of East Germany he says, "Invest if you like, but good luck. The West Germans already have it locked up."

He advises companies to be cautious about Poland. Poland's infrastructure, he says, is old and in poor condition. And, he adds, the risk of the Poles saying "no" to their experiment in democracy is great.

Orenski says Czechoslovakia and Hungary are probably the best bets for U.S. business executives. Both nations have a western-style infrastructure and a tradition of strong, industrialized market economies.

He picks Czechoslovakia ahead of Hungary only because there are fewer investors already there. Before World War II, Czechoslovakia was one of the most industrialized countries in Europe, about in the same league as Belgium. Even during 40 years of socialist rule, many Czechs were able to keep alive an entrepreneurial spirit.

The country is as well managed as any in East Europe and has a low foreign debt. Although Czechoslovakia trails Hungary in statutes on the books geared toward a market economy, observers expect it to catch up. Reforms likely will accelerate after the June elections.

Economically, Czechoslovakia is not in the best of shape, but its chemical industry is one of the largest and most rapidly growing branches of its industrial sector.

Not surprisingly, the Czech chemical industry is becoming increasingly obsolete. Producers have problems operating their plants at capacity and maintaining product quality. One indication, however, that Czechoslovakia intends to modernize its chemical industry is the rapid growth of the more advanced synthetic fibers.

Hungary is probably further down the road to a market economy than any other East European country. It certainly has been at it longer. Since 1968, despite many fits and starts, Hungary has been in the forefront of East Europe's economic reform.

It was the first East European country to begin an aggressive program aimed at privatization. It has pushed for currency convertibility and hard-currency trade relations within CMEA. Government officials have spoken publicly about closer ties with, and even eventual membership in, EC.

Despite Hungary's strong efforts at reform, its economy has been disappointing over the past two years. Gross domestic product, of which two thirds still passes through the central budget, stagnated. Deficits have exceeded estimates and inflation is a problem. A reduction in consumer subsidies and the resulting price increases have become serious political issues.

Hungary possesses few natural resources, although it does have rich bauxite deposits and lesser amounts of coal, oil, and natural gas. During the 1980s, its chemical industry was

DU PONT DE NEMOURS
DU PONT

Trade shows have given U.S. chemical firms access to East European markets

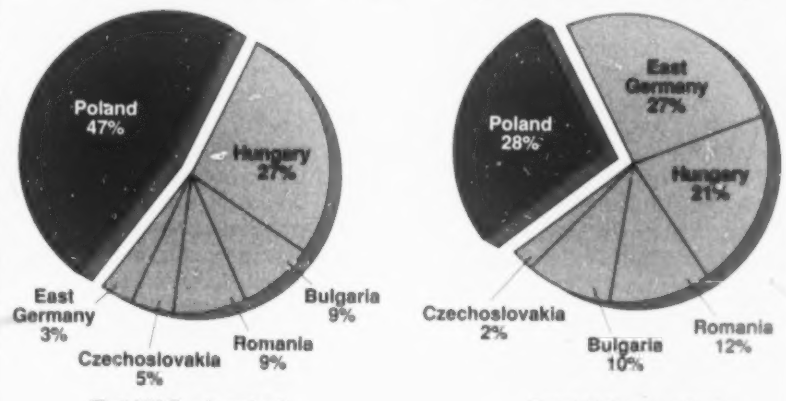
hurt by the same problems that have plagued all Hungarian industry. Chemical industry performance has been mixed, but generally bad, says PlanEcon's Mitchell. Consumer chemicals, pharmaceuticals, and plastics have expanded the fastest, but growth in basic chemical output has lagged.

The pace at which Hungary hoped to modernize its chemical industry has faltered over the past decade and the country has lost precious time in making it more internationally competitive. However, a spate of joint ventures and several World Bank loans have given new impetus to the modernization drive.

Most western business executives are bullish on Hungary. Western companies established more than 700 joint ventures there through the end of last year. Budapest, says Mitchell, could emerge as the "capital" of East Europe.

Although Hungary's reforms have come at a slow, steady pace over a long time span, Poland "is rushing like a train out of control" toward a market economy, says one observer. It wants to achieve a market economy in one or two years.

Poland is major U.S. chemical trade partner in East Europe



Total U.S. chemical exports to East Europe in 1988 = $68.6 million

Total U.S. chemical imports from East Europe in 1988 = $101.9 million

Source: Bureau of the Census

Change will be painful in Poland, however, probably more painful than in any other East European country. It is suffering through a Latin American style of inflation, about 800% per year. When price controls were lifted, prices soared. Wage increases have been pared, so that workers' pay has been cut in real terms.

Poles have endured hardships before, and most of them believe that the hardship of transforming into a market economy will be worth it in the long run. Although many U.S. business executives admire the Poles for the effort they are making, they believe that there's a big risk involved in investing there now.

Chemicals are not an important part of the Polish economy, and they probably never will be. Chemical output is small, but its growth, though lackluster, has outpaced that of industry as a whole.

What chemical industry Poland has is focused on raw materials and basic chemicals. There is very little production of high-value-added chemical products.

East Germany is different from the others in one important aspect. That difference is West Germany. East Germany has benefited and will continue to benefit from its close ties with West Germany. Moreover, a single, reunited Germany is likely soon.

Right now, East Germany's economic outlook is mixed. Growth stagnated during the late 1980s and turned negative in last year's fourth quarter. The problems of moving from a highly centralized economy to a market-oriented system will no doubt hinder economic performance, at least for this year.

The government, looking to revitalize the economy, is counting on its new joint-venture laws and further economic reforms to attract foreign investment and technology flows. Most of this will come from West Germany, but there could be room for U.S. companies as well.

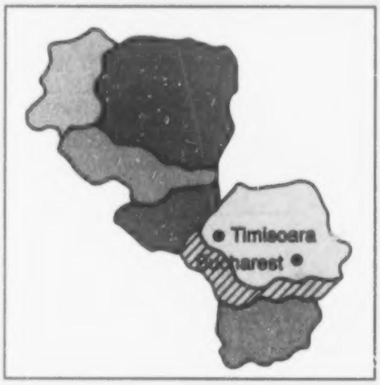
A U.S. chemical company vice president, just returned from a trip to East Germany, makes these important observations about the country:

- Most of its chemical plants are old and haven't been well maintained. It probably would be better to scrap them and start over again.

- East Germans may be Germans, but they are a product of their socialist environment. They have forgotten how to work.

West Germany's Deutsche Bank agrees that East Germany's chemical industry is outdated. In a report, the bank says that many prewar chemical plants exist alongside new petrochemical units. Productivity per worker in the East German chemical industry is about half what it is in West Germany. But even that is an improvement over the 30% that it was in 1970.

PlanEcon's Mitchell notes that the strains of East Germany's past economic policies have slowed growth in its chemical industry. The government pushed exports at all costs. In the process, it neglected investment and plant modernization. The consequences now are becoming apparent and won't disappear for some time. If not corrected, East Germany could lose its standing as one of East Europe's leading chemical producers.



Romania in brief

Size: 91,699 square miles

Population (1989): 23.2 million

GNP (1988): $126.3 billion

GNP per capita (1988): $5491

World trade:

Imports (1988): $8.0 billion

Exports (1988): $10.5 billion

Telephones per 100 people (1985): 13

Automobiles registered per 1000 people (1986): 11

Romania, consisting of two fertile areas—the Transylvanian plateau and the plains of the coastal south and east—divided by the crescent of the Carpathian Mountains, has rapidly become urbanized and industrialized since World War II.

Steel and other metals, machinery, oil products, chemicals, wood products, textiles, and food processing are among its important industries. Mineral resources include oil, gas, and coal. Forestry is also important. Leading crops are grain, vegetables, oil seeds, and grapes, and sheep breeding is significant. Romania's major imports include machinery and such raw materials as fuel, iron ore, and coking coal. Significant exports include foodstuffs, light manufactures, and wood products.

The Romanian economy was marked by rigid centralization during the 1980s, and its foreign trade declined as payment of external debt became a top economic priority of the former communist government. Foreign investment was discouraged. The government now in power, however, has taken significant steps to normalize trade and liberalize conditions for foreign investment.

Trade may be a better way to go than investment

Those conditions that exist in East Europe make investing there extremely risky. Many U.S. companies may not want to take that risk. For them, exporting is one solution.

However, East Europe has never been much of a factor in the U.S. chemical export picture. In 1988, U.S. chemical exports to the six East European countries were a lowly $68.6 million. That's only 0.2% of total U.S. chemical exports that year ($32.3 billion) and is a mere shadow of the $10 billion in chemicals that U.S. companies shipped to West Europe.

Of the $68.6 million in U.S. chemicals shipped to East Europe in 1988, almost half—$32.4 million—went to Poland. Poland is by far the largest U.S. chemical trading partner in East Europe. Not only does Poland account for the largest share of East European imports from the U.S., it also leads all East European countries in exporting chemicals to the U.S.

Hungary is next in line as an East European importer of U.S. chemicals, with $18.4 million worth in 1988. Together, Poland and Hungary account for almost three quarters of the U.S. chemicals sent to East Europe. U.S. chemical exports to the other four East European countries fall below $6 million for each of them—in some cases, well below.

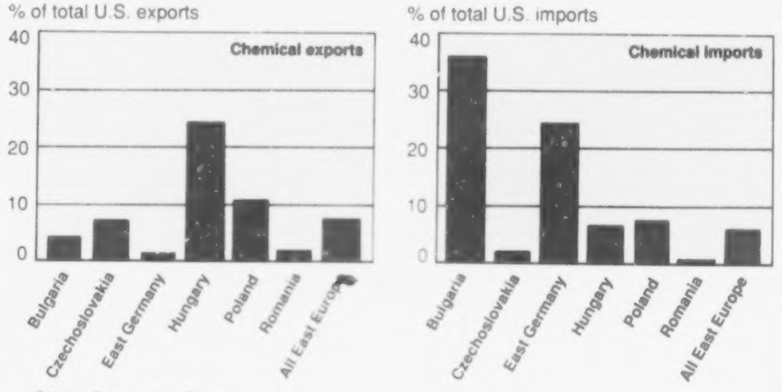
According to PlanEcon, the six East European countries imported almost $6 billion from nonsocialist sources in 1988. That means that the $68.6 million in chemicals the U.S. exported to East Europe in 1988 represents only 1.2% of all nonsocialist exports to the region.

PlanEcon measures East European chemical trade in three ways. It measures total trade of an East European country in its local currency. It uses rubles for trade within the socialist bloc and dollars for trade with nonsocialist areas.

Trying to convert rubles and nonconvertible local currencies into dollars is like comparing apples and oranges, says Mitchell. "There is no meaningful way," he says, "to compare socialist and nonsocialist trade." The reason is that it's next to impossible to know what the "true" exchange rate is. The official exchange rate is meaningless for all practical purposes. And the black market rate can be as much as 10 times higher than the official rate.

The rate at which trade should be measured lies somewhere in between, but nobody knows exactly where. Even the theory of "purchasing power parity" won't work because huge differences in quality of socialist and nonsocialist goods make comparisons difficult. The only accurate way to compare socialist and nonsocialist trade is to use volumes rather than values. But because so many diverse products are included in the chemical trade category, even this method becomes unwieldy.

For some East European countries, chemicals account for a big share of total U.S. trade



Source: Bureau of the Census

The United Nations computes its trade data at the official exchange rate. But despite this caveat, UN data for 1987 does confirm the obvious—U.S. chemical exports to East Europe are not only a small piece of the U.S. export pie, they are a small piece of the East European chemical import pie as well. According to the UN, East Europe imported $7.0 billion worth of chemicals in 1987. Of that, $3.1 billion came from the Soviet Union or was inter-East European chemical trade. Most of the remaining $3.9 billion came from nonsocialist sources (compared with PlanEcon's $5.5 billion in 1987).

UN statistics indicate the U.S. exported only $79 million in chemicals to East Europe in 1987, which compares well with U.S. Bureau of Census data ($80 million). But that $79 million is only 1% of East Europe's total chemical imports and only 2% of its imports from nonsocialist areas. Even Japan exports more chemicals to East Europe than the U.S. If PlanEcon's figures for nonsocialist chemical imports are used, the U.S. share would be even less.

Not surprisingly, the overwhelming share of East Europe's nonsocialist chemical imports come from West Europe. Based on UN data, West Europe accounts for 81% of nonsocialist exports to East Europe. West Europe, in fact, ships more chemicals to East Europe than the combined total chemical exports from the U.S.S.R. and between East European countries themselves.

Despite the small volumes of chemicals that the U.S. exports there now, and despite the commanding lead that West European companies have in the market, U.S. chemical companies can develop sizable export markets in East Europe if they are willing to make the effort.

Vincent J. Kamenicky, director of the office of chemicals and allied products at the Department of Commerce, knows the East European chemical scene and the people in it very well. As a U.S. delegate to the chemical industry committee of the Economic Commission for Europe, he meets with them often.

Kamenicky says that the East Europeans he knows often ask about the availability of chemicals from the U.S. To promote U.S. chemical exports, he tries a different approach. He asks what chemical products the East European countries have to sell that aren't made in the U.S., then tries to find U.S. buyers for them. "If we have to import and they meet our quality requirements, why not import from East Europe," he asks.

The bottom line of this exercise is that, once U.S. companies import from East European countries, they remember it. When the time comes for these countries to import chemicals, they buy from the U.S. So far, says Kamenicky, every import he has engineered from an East European country has resulted in an export sale.

The export markets are there already, and they are likely to grow substantially if East European countries are able to get their fledgling market-based economies in order.

Between 1980 and 1988, East European chemical imports from nonsocialist areas increased just under 3% per year, according to PlanEcon's Mitchell. But between 1988 and 1994, PlanEcon had projected that those imports would grow a hefty 10.5% annually, reaching $10.9 billion by 1994.

Those projections were made last fall. Now, says Mitchell, "that rosy forecast may have to be toned down a little." At the time that they were made, PlanEcon didn't anticipate that economic reforms in East Europe would advance as rapidly and as dramatically as they have. Nor did the company anticipate the severity of the impact that these reforms would have on the economies of East European countries.

Mitchell agrees with many other East European experts that, economically, things may get worse there for a few years before they get better. The transition to a market economy may impel these countries to cut imports before they will be in a position to increase them. Still, East Europe is an export target that U.S. chemical companies could find well worth shooting for.

A lot of western money is pouring into East European countries to help them convert to market-based economies. And a latent consumer demand will have to be met by increasing imports until their outmoded chemical plants are refurbished or replaced. This consumer demand, says Mitchell, will create export opportunities for western chemical companies.

The U.S. share of nonsocialist chemical exports bound for East Europe should increase, says Mitchell. One reason for his optimism is that East European countries admire U.S. quality. And they don't want to become overly dependent on imports from West Europe.

He also believes that U.S. chemical companies who have never exported to East Europe before will get into the act. They, along with the larger multinationals who have a long history of exporting to socialist countries, will be able to provide the high- value-added products that will be needed in these markets.

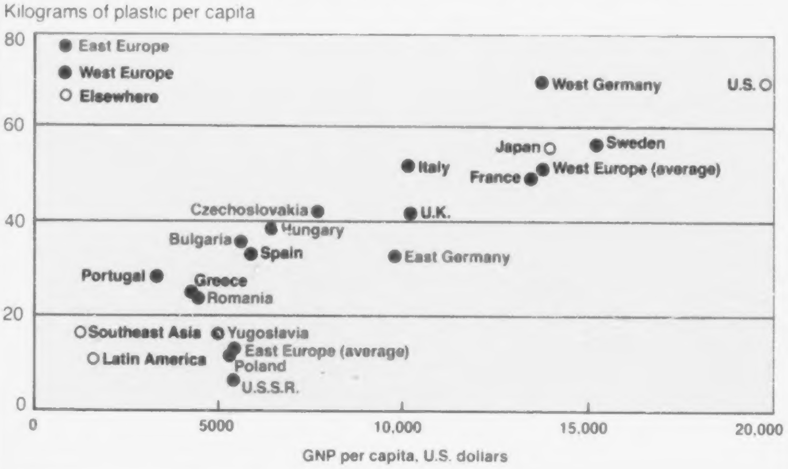
Such products as heavy inorganics and organic commodities will not be promising because transportation costs are too much of a factor. Besides, East European countries usually produce these chemicals themselves or can obtain them easily from neighboring West European or other East European countries. It is in the high-value-added products that Mitchell believes U.S. chemical companies can carve out sizable niches in East European demand.

One possible complication in estimating the future export potential of U.S. chemical companies could come next year, when the U.S.S.R. and the socialist countries of East Europe plan to move to trade based on hard currencies. One school of thought contends that this move will benefit the Soviets, who will then be able to charge higher prices for their exports to East Europe. On the other hand, they may be forced to keep export prices down for competitive reasons.

In addition, some East European countries may seek pricing concessions from the Soviets, or at least attempt to get a transition period during which the Soviets will grant them concessionary prices. Other countries may welcome the jolt that hard-currency trade will bring because it will force them to become more efficient.

Certainly without hard, convertible currencies, trade among socialist countries has been distorted. In some cases, these countries have used a five-year moving average of world market prices, which leaves them out of step with current world prices.

East Europe's use of plastics is relatively low overall . . .



. . . but especially so for polystyrene and polypropylene

Per capita consumption, kg	Linear low-density and low-density polyethylene	High-density polyethylene	Polypropylene	Polyvinyl chloride	Polystyrene
Bulgaria	9.8	3.9	5.6	11.7	3.9
Czechoslovakia	9.0	3.7	10.7	11.3	5.9
East Germany	12.2	2.2	5.1	14.8	1.6
Hungary	11.2	6.2	6.0	10.2	4.3
Poland	3.4	0.5	1.9	4.9	1.2
Romania	5.4	3.4	3.8	7.7	1.8
Japan	9.9	6.6	12.7	14.4	8.0
U.S.	18.5	13.9	11.3	14.7	9.3
West Europe	14.1	7.1	8.2	13.5	6.0

Sources: Tecnon Ltd., Shell, PlanEcon

Although the switch to hard currency trading is not a sure thing, the Soviet Union holds most of the trump cards. And the Soviet Union wants to switch to hard currency.

Another imponderable is the impact that petrochemical imports from the Middle East may have on the battle for East European markets. The Soviet Union remains the logical supplier of petrochemical feedstocks for those East European countries that do not have them. But, depending upon how pricing evolves under hard-currency trading, the Middle East could become a competitive supplier of feedstock and other petrochemicals.

Most East European countries have extended aid and credit to developing countries, including some in the Middle East. They would welcome the opportunity to get repaid with something that they could import from that region. What's more, many consumer goods produced in East Europe, which do not have the quality to be exported to the industrialized west, could find a less-demanding market in the Middle Eastern countries. As a result, a Middle East-East Europe trade buildup is more than a fantasy. Despite the imponderables, it's more than likely that the six East European countries will continue to increase their hard-currency chemical imports from nonsocialist areas.

Meanwhile, economic reforms under way in some East European countries aim to modernize pitifully antiquated industries. This is especially true in Hungary and Poland and, to a lesser extent, in Bulgaria and Czechoslovakia. To accomplish the task, these countries will need chemicals used to make other industrial products. Examples: better paint for manufactured goods, packaging for food and other products, construction materials, and better plastics for cars and trucks.

But perhaps the most important reason of all for anticipating that East Europe will increase its chemical imports from nonsocialist areas is that the old, inefficient "command" economic system has not yet disappeared there. Although the transformation to a market-based economy is well under way, the old system still predominates. And with it remain uneven and uncertain economic performance and temporary shortfalls in output. These are shortfalls that must be met by chemical imports—including imports from the West.

The trend already is evident. East European chemical imports from nonsocialist areas declined in the early eighties, primarily because of a mounting debt crisis and the austerity programs that accompanied that crisis in many East European countries. Non-socialist chemical imports hit a low in 1982, but have rebounded since then to almost $6 billion in 1988.

East Germany accounted for $1.6 billion, or 27% of this amount. Poland and Hungary are close behind at $1.4 billion and $1.2 billion, respectively. The extensive "inner-German" trade that takes place between East and West Germany explains the relatively high level of East Germany's nonsocialist chemical imports. It also explains why the U.S. only exported $2.3 million worth of chemicals to East Germany in 1988. That's the least shipped to any of the six East European countries, and less than half what the U.S. exported to even Bulgaria or Romania.

However, Bulgaria and Romania aren't much of a factor when it comes to importing chemicals from nonsocialist countries. In 1988, such imports into Romania were only $279 million. For Bulgaria, the figure was $515 million, according to PlanEcon.

However, PlanEcon's Mitchell sees little hope of western-based companies increasing their chemical exports to Bulgaria. These shipments, he says, will be tempered by the mounting Bulgarian debt and the consequent balance-of-payments problems. He projects only an average 6.4% per year growth for Bulgarian nonsocialist chemical imports through 1994. By then, Bulgaria will still remain the smallest market in East Europe for western chemical products by a wide margin.

Romania is a different story. Its fallen dictatorial leader, Ceauşescu, clamped an extremely tight austerity on the country—far tighter than required to service its foreign debt. As a result, Romania's nonsocialist chemical imports plummeted from $605 million in 1980 to $263 million in 1987.

The foreign debt has been repaid, but Romania's economy has paid the price. It is in shambles. Lacking the ability to produce its own chemical needs, the country's chemical imports from the West will recover dramatically, Mitchell thinks, with an estimated 24% average annual growth through 1994.

Western chemical export potential to Hungary and Poland is difficult to predict, says Mitchell. In Hungary, the bad news is that a decade of poor economic performance clouds the possibility that chemical imports from the West will rise significantly. The good news is that talk of radical economic reform provides some hope.

Hungary's nonsocialist chemical imports were essentially stagnant between 1980 and 1988. And although PlanEcon expects growth to be uneven over the next few years, it estimates that the country's imports of western chemicals will increase an average 5% per year, hitting $1.67 billion in 1994.

The economic crisis in Poland, triggered by its "cold turkey" switch to a market-based economy, also makes the potential for exporting chemicals to Poland uncertain. The country's nonsocialist chemical imports stagnated between 1980 and 1985 at just below $1 billion. Then they grew rapidly to $1.4 billion in 1988. PlanEcon expects Poland's nonsocialist chemical imports to continue growing, but growth will be limited by economic problems. PlanEcon's best guess: "modest increases" to just above $2 billion by 1994.

West Germany makes East Germany unique among East European countries. The bulk of East Germany's nonsocialist chemical imports comes from West Germany. That will not change until, of course, East and West Germany reunify.

For now, at least, East Germany remains the largest importer of western chemicals in East Europe. These imports almost doubled to $1.6 billion from 1980 and 1988. They may double again, says PlanEcon, to $3 billion by 1994. With reunification, however, there will be no such entity as East Germany.

Knowing what chemicals these countries will need is just as important as knowing where the best export markets may be in East Europe. Between 1980 and 1988, organics were the largest category of chemicals that East Europe and the Soviet Union imported from western industrialized countries, accounting for almost 25% of the total.

Organics imports included a wide variety of chemicals, an indication that East European countries, with the possible exception of Czechoslovakia and East Germany, lack a well-developed organic chemicals industry. This lack means that most East European countries, particularly Romania, should continue increasing their imports of the basic organics. Among the leading organics that they import now are xylenes, styrene, vinyl chloride, alcohols, phenols, carboxylic acids, and terephthalic acid.

East Europe imports large amounts of inorganics, too. Countries there already produce large volumes of the basic inorganics, such as sulfuric acid, caustic soda, and soda ash.

They probably will try to keep nonsocialist inorganics imports as low as possible and keep their scarce hard currency available to import organics, plastics, and other more sophisticated chemical products. Western companies can expect only a modest expansion of inorganic imports from the East European countries.

Because East Europe produces vast amounts of fertilizer, its fertilizer imports have been among the smallest of any chemical category. Nevertheless, East Europe doesn't produce enough of certain kinds of fertilizer to meet its own demand.

Large tonnages of products, such as concentrated and compound fertilizers, superphosphates, and potassium fertilizers, are imported from the West. And since some East European countries have explicitly said that the trend is toward the more complex and higher analysis fertilizers, they will have to continue importing them. Recent disappointing crop harvests will add to their fertilizer import demand.

The Soviet Union and other East European countries, particularly Hungary and Poland, have been large importers of western plastics and resins. Plastics, in fact, rank only behind organics as the largest East European chemical import from nonsocialist countries.

The plastics revolution, says Mitchell, still hasn't hit East Europe. There will be opportunities for western companies to supply plastics for every aspect of East European industrial and everyday life. Although several plastics plants have been or soon will be completed in the region, countries there still must rely on imports to satisfy demand.

Despite recent hikes in output, the area still is short of polyethylene and polyvinyl chloride, and probably will continue to be for years as production shortfalls crop up. These polymers will be imported. Polypropylene and polystyrene production is still in its infancy in East Europe. Imports, primarily from the West, will be a must. So, too, will be imports of engineering resins because it will take years for East European countries to build up their domestic capacity.

Another reason why western companies can anticipate exporting more plastics and resins to Eastern Europe is the possibility that plant accidents could shut down a plant and disrupt local production. It happened in Devnia in 1986, when an explosion nearly wiped out 1987 Bulgarian PVC production and forced the country to rely on additional imports from western suppliers. It could easily happen again anywhere in East Europe.

Western suppliers, including U.S. companies, can expect demand for many more sophisticated, high-value-added products to increase in East Europe. For instance, East European imports of paints, dyes, and other coloring agents should grow rapidly simply because they are not available from domestic sources.

No one ever said that converting from a hard-line communist society to a democratic society based on free market principles would be easy for East European countries. So, too, should imports of finished medicinals and pharmaceuticals, which are extremely short in some East European countries.

And it won't happen overnight. It will take years. This combination of time and hardship leaves open the question: Will some of the East European countries call it quits and revert to a socialist society?

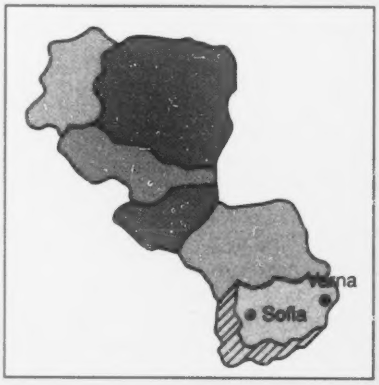
Although most East European experts doubt that this will happen, they by no means claim that it couldn't happen. The hardship now ravaging Poland, for instance, may be a steeper price than Poles may be willing to pay for much longer.

But Orenski points out that the Poles have maintained a lot of discipline in the face of astounding changes and hardship. He and other East Europe watchers believe that the Polish people will not surrender to their difficulties and will see the transition through. Others point out that their hatred of anything communist will guarantee it.

There are many questions. What if the good times under a market economy don't come as rapidly as East Europeans expect—or hope? What if converting to a capitalistic system turns out to be long and difficult? Will East Europeans become tired of shouldering the burden that comes with the transition and opt for a return to socialism?

Romania is also a possible candidate to give up on a complete switch to capitalism. Romanians have long been accustomed to authoritarian rule. Some experts cautiously express the view that a reversion to a Ceauşescu-type rule, without the ruthlessness, is not completely out of the question.

These are difficult, if not impossible, questions to answer. The popular response is: "It's unlikely." Still, it's a question that cannot be ignored. But, as Ethyl's Turnipseed says, nobody will have the answer for at least another five years. ☐



Bulgaria in brief

Size: 44,365 square miles
Population (1989): 9.0 million
GNP (1988): $67.6 billion
GNP per capita: $7540
World trade:
  Imports (1988): $4.46 billion
  Exports (1988): $2.45 billion
  Telephones per 100 people (1985): 20
  Automobiles registered per 1000 people (1986): 120

Bulgaria is the smallest of the East European countries in terms of population and national output but also has enjoyed perhaps the highest rate of investment and economic expansion in recent years. Its rapid growth, however, has resulted in exports failing to keep up with imports and a deteriorating balance of trade.

Largely self-sufficient in agriculture, the country grows grain, fruit, corn, potatoes, and tobacco. Important mineral products include lead, bauxite, and low-grade coal. Major industries include chemicals, machinery, textiles, fur and leather goods, and food processing. Major imports include machinery, fuels, mineral raw materials, and chemicals; major exports include machinery, foods, textiles, and such chemical products as fertilizers and rubber.

Because of its small size, U.S. trade and investment is relatively low. Bulgaria's harsh treatment of its Turkish minority in recent years has strained relations with the U.S. However, the country has enacted economic reforms, including legal rights for private investment and a law permitting 100% foreign ownership, in the past two years to attract foreign trade and capital.

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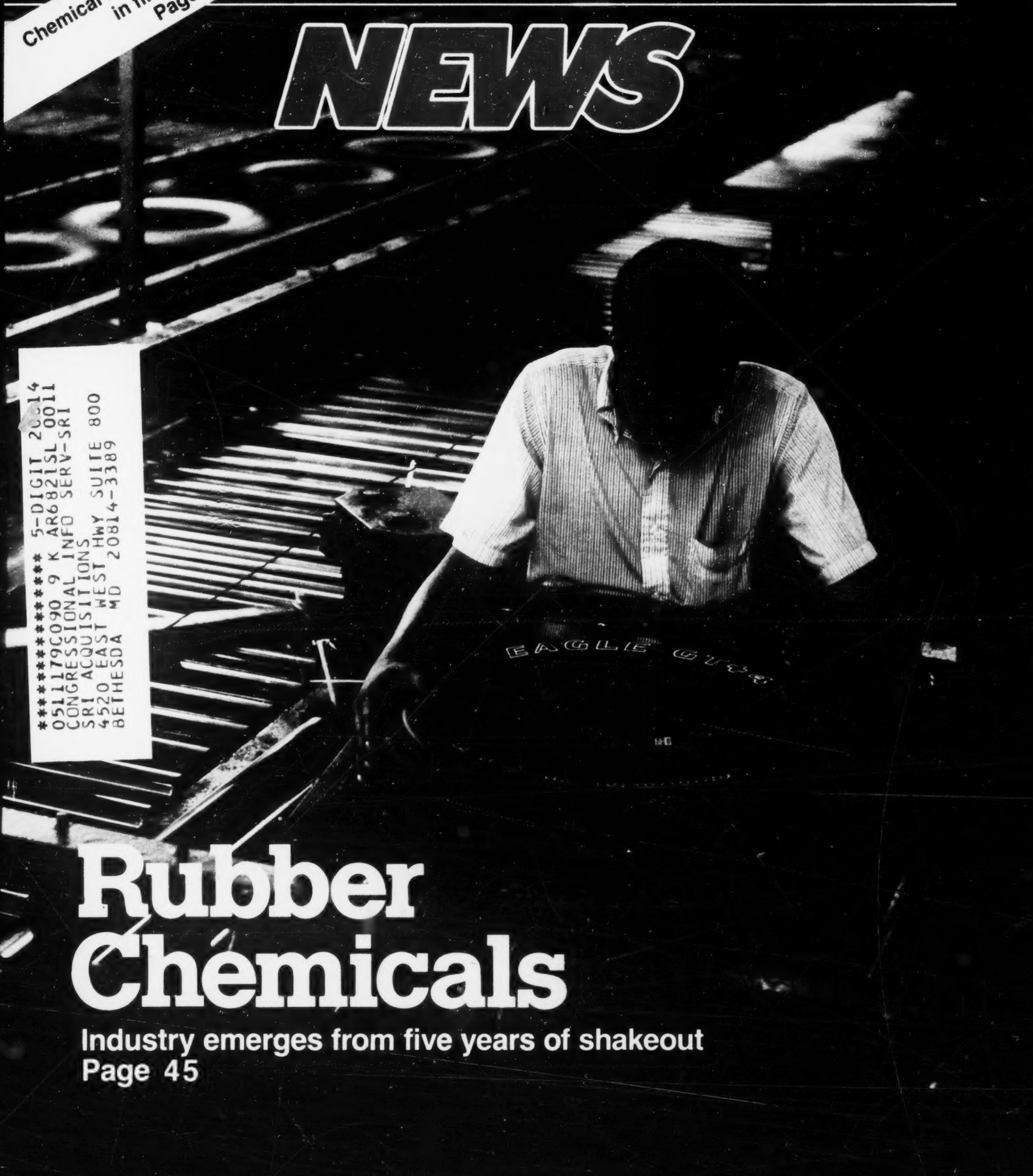
MAY 21, 1990

CHEMICAL & ENGINEERING

NEWS

Chemical industry earnings down in first quarter
Page 12



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Rubber Chemicals

Industry emerges from five years of shakeout
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Volume 68, Number 21
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CHEMICAL & ENGINEERING
NEWS
MAY 21, 1990

News of the Week

- **Tufts researcher Thereza Imanishi-Kari may face criminal inquiry as part of ongoing probe into allegations of scientific misconduct relating to paper published in 1986 by her, Nobel Laureate David Baltimore, and coworkers.** Page 6
- **CIA report assesses East Europe's economic prospects, says formidable barriers to genuine economic reforms still lie ahead.** Page 7
- **Library of Congress ponders National Library of Science & Technology** Page 7
- **Ciba-Geigy to sell its San Jose, Calif.-based Spectra-Physics subsidiary.** Page 8
- **West Germany's BASF, Bayer, and Hoechst form a consulting venture for the recycling of plastic wastes.** Page 8

Cover: Photo courtesy of Goodyear

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Business

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Government

U.S. motor fuels policy is being scrutinized by newly formed Alternative Fuels Council; OTA report finds policy lacking in high-temperature superconductivity; FDA permits use of zidovudine to treat AIDS in children; focus groups are helping write long-awaited acid rain report. **Page 25**

Science/Technology

From the Boston meeting: Advances in homogeneous catalysis broaden scope of process chemistry; progress in mild gasification approach renews interest in coal conversion; unique form of cellulose produced in fermenters is nearing commercialization; laser-based molecular fluorescence spectrometry offers sensitive new analytical methods; chemical markers produced when foods are heated can establish sterility of processed food. In other news: puzzle of ozone hole's hidden chlorine chemistry appears to be solved. **Page 30**

Books

Current-day science in the U.S.S.R. is reassessed and critiqued in two books, "Techno-diplomacy: US-Soviet Confrontations in Science and Technology" and "Soviet Science on the Edge of Reform." **Page 69**

Product Report

Although many mergers, restructurings, and other changes have occurred to the U.S. rubber-processing chemicals industry in the past five years, the industry is strong and is slowly growing. Page 45

Chemical & Engineering News

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LETTERS

Spokesman for chemistry

SIR: On reading James Krieger's report (C&EN, Jan. 29, page 28) of Roald Hoffmann's remarks at the Honolulu symposium on the public's perception of chemistry, I could only think that Hoffmann must be bucking for a second Nobel Prize—for peace! If he continues with his humble, humane approach to the public's fear of our profession and its attacks on our activities, he might just gain sufficient credibility to bring this era of confrontation to an end. Hoffmann has my vote as chief spokesman for the profession.

David M. Mog
Arlington, Va.

Attracting scientists

SIR: A continuum of explanations has appeared regarding the failure of our educational systems to produce high-quality chemists, physicists, and engineers. Buried among these explanations is money; I believe money is the principal factor. Youngsters do not see an environment that is attracting them to the sciences.

In today's heterogeneous societies, with childcare, nursery schools, busing, etc., youngsters are befriending a large spectrum of children from a variety of socioeconomic backgrounds. When children are invited to each others' homes, they see the gambit—from subsidized city housing to magnificent estates.

Whom do you find living in the beautiful homes? Which children go on winter vacations to ski resorts or to tropical paradises? Which families have summer homes, fancy cars, live-in help, inground pools, etc.? Which children go to posh sleepaway camps, private schools, and expensive colleges? Whose children get fancy cars when they reach 16 or enter college?

Often these families are headed by physicians, dentists, veterinarians, lawyers, accountants, investment bankers, and successful business people. Very few are the working chemist or engineer unless they won the state lottery; and TV sitcoms help reinforce this picture. Youngsters are impressionable; parents are too. Scientists don't lead the so-called great life; and if that's what you want, you'd better look elsewhere for a profession.

When all this is coupled with the hardships associated with majoring in science or engineering in college, one could almost conclude that only the misguided wind up in these disciplines aiming to get a Ph.D. And maybe there's some truth to that. An adolescent who is strongly intimidated by the people interactions associated with being a lawyer, physician, dentist, Wall Street wheeler-dealer, etc., is much more comfortable as the loner scientist—the "nerd" syndrome. Maybe society is generating too many well-rounded youngsters, reducing the pool of talent who consider becoming scientists.

Look at the ACS statistics (C&EN, July 3, 1989, page 31). Three quarters of the nonacademic chemistry Ph.D.s with 15 to 19 years of experience beyond the B.S. degree (men and women in their late thirties and early forties) earn less than $61,000. Meanwhile, youngsters graduating from the high end of their law schools are starting today at over $80,000, at least in major New York City law firms. There are no mechanisms in place today where a 24- or 25-year-old Ph.D., regardless of what school, which professor, or how good, can start a career at a major chemical company at over $80,000. When scientists can earn what lawyers, physicians, dentists, and investment bankers earn, or are perceived to earn, the concerns about the future supply of high-quality scientists will disappear.

Robert Rabinowitz
Technical Director, Flocculants and Reagents, American Cyanamid Co.

Good teachers, better students

SIR: I would like to respond to Tom Castle's letter (C&EN, March 12, page 2) regarding the statements he made about high school teachers. I love to teach science and kids, but teaching is not easy if you do it right. I have been a high school chemistry and physics teacher for six years, a graduate teaching assistant, and this year have taught organic chemistry part time at a local community college. Omitting my part-time teaching at night, I average 10 working hours a day at school, teaching six classes with four different subject preparations. I also av-

Correction

- April 30, page 35: California Institute of Technology should have been ranked eighth on the listing of major producers of Ph.D. chemists in 1988–89 with 34 such graduates.

Chemical Earnings Tumble In First Quarter

Declining prices, rising costs, slipping sales have combined to push profits down at many chemical companies; oil and diversified firms also see fall

William J. Storck,
C&EN Northeast News Bureau

The first quarter was pretty much on target for chemical company earnings. A downturn in chemical earnings was expected and that's what happened. Various combinations of falling prices, rising costs, and declining sales volumes caused earnings to decline at many firms. However, most chemical executives still see a good year in total.

Nevertheless, the first quarter was not a particularly good way to start the year. Earnings at 30 major chemical companies surveyed by C&EN fell an average of 26% from last year's first quarter. The bottom line was also down at oil companies and diversified firms that produce chemicals. And earnings suffered at major pharmaceutical companies, although this was a case of one company's results dragging down the whole group.

Government data tell part of the story. Prices for chemicals and allied products in the first quarter averaged 2.0% lower than they did in the same period in 1989. And chemical production was up only a little more than 1% from last year's first quarter.

More telling perhaps were the shipments and inventories figures released by the government for the first quarter. The Commerce Department reports that shipments of chemicals and allied products in the first three months of this year were essentially level with the same period in 1989. And for industrial chemicals, shipments for the first quarter fell 4.6% on a seasonally adjusted basis.

At the same time, inventories increased in chemicals and allied products, probably more than soaking up the increase in production. Inventories of chemicals and allied products rose about 2% over the previous year. And inventories for industrial chemicals were essentially unchanged from the year-earlier quarter.

Continued softness in downstream and end-use markets was the key to chemicals' performance. Automobile sales and production remained at low levels and the residential housing market continued soft. Commercial building also was sustaining lower levels than in the past few years.

Demand in the agricultural sector, though up from just a few years ago, still did not provide the boost needed for earnings at the major fertilizer companies. And durable goods orders and shipments were well down from the first three months of 1989.

Since all of these markets are big users of chemicals, it is no wonder that the industry had its problems during the quarter.

Adding to that was the export situation. Although shipments of many chemical products out of the U.S. seemed to hold up on a volume basis and, in fact, increased in some cases, the selling price of those exports fell, according to many industry observers.

Chemical industry leaders for first-quarter 1990

Sales

Rank 1990		$ Millions	Rank 1989
1	Dow Chemical	$4900.0	1
2	Monsanto	2286.0	2
3	Union Carbide	2173.0	3
4	W. R. Grace	1507.3	4
5	American Cyanamid	1272.7	5
6	Hercules	771.4	7
7	Air Products	713.1	10
8	Rohm & Haas	694.4	9
9	Arco Chemical	685.0	8
10	Quantum Chemical	682.8	6

Earnings[a]

	$ Millions	Rank 1989
Dow Chemical	$462.0	1
Monsanto	194.0	2
Arco Chemical	125.0	4
Union Carbide	94.0	3
American Cyanamid	90.9	5
Air Products	54.3	9
Rohm & Haas	54.1	8
Ethyl	52.4	10
International Flavor	41.6	13
Morton International	39.1	14

Profitability

	Earnings as a % of sales	Rank 1989
Arco Chemical	18.2%	4
International Flavor	17.2	3
Georgia Gulf	14.9	2
Great Lakes Chemical	13.6	1
Loctite	11.8	7
Betz Laboratories	10.7	8
Nalco Chemical	10.4	9
Dow Chemical	9.4	4
Vista Chemical	8.8	6
Morton International	8.7	16

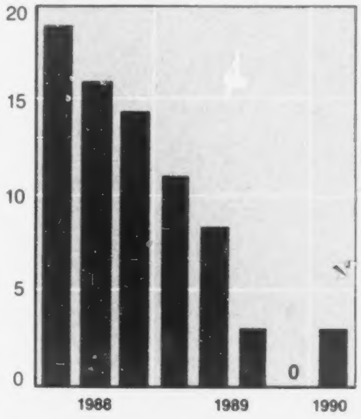
Note: Based on 30 chemical companies listed on page 14. a After taxes.

Chemical industry 1990 first-quarter results

- Sales rose 3%
- Earnings dropped 26%
- Profitability fell to 7.3%
- Production increased 1%
- Prices were down 2%

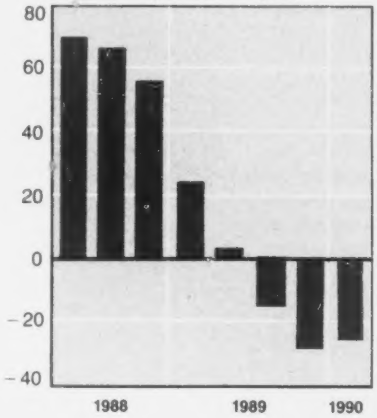
Sales

% change from year-earlier quarter



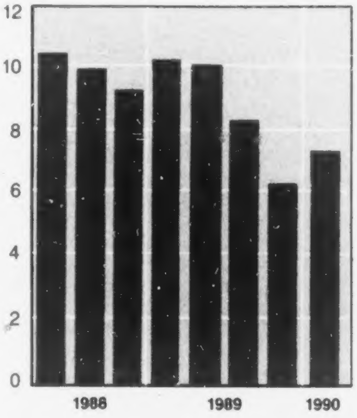
Earnings

% change from year-earlier quarter



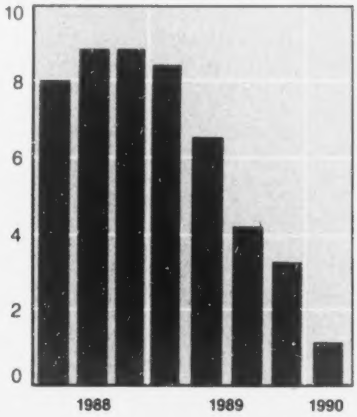
Profit margins

After-tax earnings as % of sales



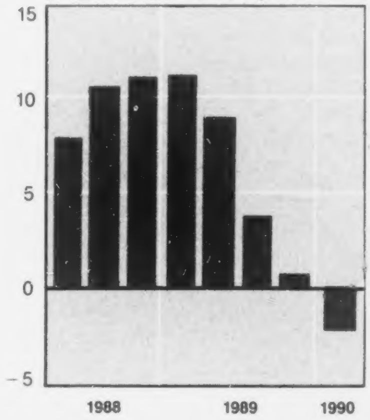
Production

% change from year-earlier quarter



Prices

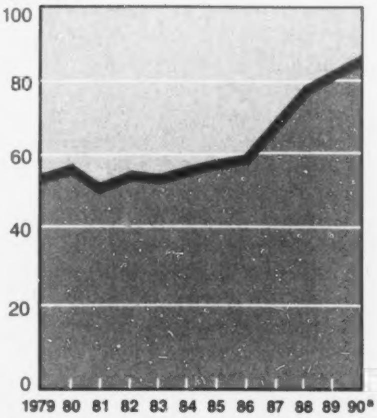
% change from year-earlier quarter



Sales in 1990 will rise about 4% while earnings will be flat, lowering profit margins to about 8.3%

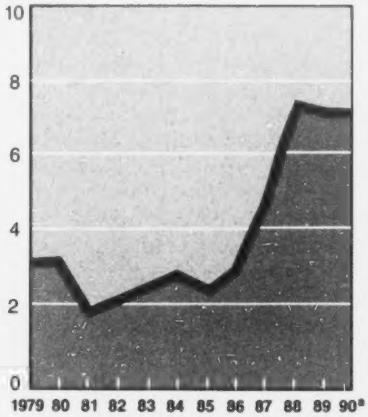
Annual sales

$ Billions



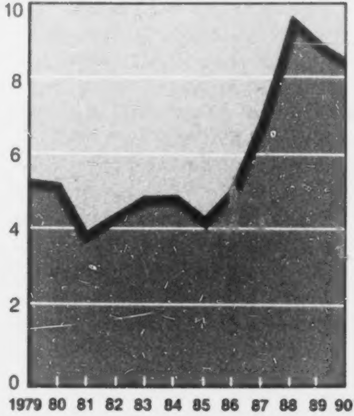
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit margin data are based on 30 chemical companies listed on page 14. a C&EN estimates.

Earnings at major chemical companies fall 26% in first quarter

	FIRST-QUARTER 1990						12-MONTH RUNNING DATA			
	Sales	Earnings[a]	Change from 1989		Profit margin[b]		Change from 1989		Profit margin[b]	
	($ millions)		Sales	Earnings	1990	1989	Sales	Earnings	1990	1989
Air Products	$ 713.1	$ 54.3	7%	5%	7.6%	7.7%	6%	−6%	7.7%	8.7%
American Cyanamid	1,272.7	90.9	3	7	7.1	6.9	4	−4	6.3	6.7
Arco Chemical	685.0	125.0	−2	8	18.2	16.6	−6	−18	15.6	17.8
Betz Laboratories	143.3	15.4	15	17	10.7	10.6	15	15	10.8	10.8
Cabot	455.1	15.0	−16	−47	3.3	5.2	−4	−48	2.1	3.9
Chemed	143.9	4.2	1	−21	2.9	3.7	9	15	4.2	4.0
Crompton & Knowles	94.4	6.9	8	30	7.3	6.1	6	41	7.2	5.4
Dow Chemical	4,900.0	462.0	9	−38	9.4	16.6	5	−17	12.2	15.4
Ethyl	609.7	52.4	7	3	8.6	9.0	7	−3	9.4	10.4
First Mississippi	116.9	1.3	−1	−85	1.1	7.3	26	−97	0.2	8.4
H. B. Fuller	181.5	1.6	2	−16	0.9	1.1	7	−16	2.0	2.6
Georgia Gulf	251.6	37.4	−21	−32	14.9	17.4	−10	−17	16.8	18.2
B. F. Goodrich	589.8	16.2	−4	−68	2.7	8.3	−5	−41	5.7	9.2
W. R. Grace	1,507.3	32.6	8	8	2.2	2.2	6	6	3.3	3.3
Great Lakes Chemical	252.3	34.3	74	20	13.6	19.7	60	19	14.3	19.1
Hercules	771.4	33.7	4	−25	4.4	6.1	11	−44	2.5	5.0
International Flavors	241.4	41.6	6	8	17.2	16.9	5	8	16.0	15.6
International Minerals	371.7	18.7	43.8	−21.8	5.0	9.2	31	−16	5.2	8.0
Loctite	133.9	15.8	15	12	11.8	12.1	10	17	12.2	11.5
Lubrizol	355.5	29.1	4	−5	8.2	8.9	7	−4	7.5	8.3
Monsanto	2,286.0	194.0	1	−13	8.5	9.8	3	2	7.1	7.2
Morton International	447.1	39.1	12	13	8.7	8.7	11	−3	7.9	9.0
Nalco Chemical	284.8	29.7	14	18	10.4	10.1	10	17	11.2	10.5
Olin	636.0	32.0	0	−6	5.0	5.3	3	18	4.9	4.3
Petrolite	72.0	3.6	0	18	5.0	4.3	−1	11	4.4	3.9
Quantum Chemical	682.8	5.8	−16	−92	0.8	8.8	−20	−76	3.6	11.9
Rohm & Haas	694.4	54.1	2	2	7.8	7.8	3	−20	6.6	8.5
Union Carbide	2,173.0	94.0	−3	−53	4.3	9.0	1	−36	6.0	9.5
Vista Chemical	183.8	16.2	−7	−50	8.8	16.4	−4	−30	12.0	16.4
Witco	395.2	14.5	−1	−15	3.7	4.3	−1	−10	4.6	5.0
TOTAL	**$21,646.0**	**$1571.5**	**3%**	**−26%**	**7.3%**	**10.1%**	**3%**	**−18%**	**7.9%**	**9.9%**

a Earnings from operations excluding significant nonrecurring and extraordinary items. b Earnings as a percentage of sales.

Although all of this resulted in a large drop in chemical earnings, it must be remembered that the earnings for the first quarter are still being compared with earnings from a very heady period of growth for the industry that lasted into the second quarter of 1989.

Combined earnings for C&EN's sample of 30 chemical companies fell 26% to $1.57 billion on a sales increase of about 3% to $21.6 billion. The result was that the average profit margin (after-tax earnings as a percentage of sales) dropped to 7.3% in the first quarter of 1990 from 10.1% in the comparable period last year.

Though the nearly three percentage point drop seems large, an average profit margin of 7.3% is still high for the chemical industry on a historical basis.

Further clouding the picture is the split between the large and commodity-oriented companies and the smaller to medium-size companies. If just two companies, Dow Chemical and Union Carbide, are pulled from the list, the remaining 28 firms had an average earnings decline of just 14%. Then take out Quantum with its huge 92% earnings fall and the decline for the 27 firms remaining drops to 9%. Although 16 of the 30 companies surveyed showed declines in earnings, only eight of these were greater than the average for the full list of companies. Thus, these eight had a disproportionate effect on the average decline for the group.

And among the 14 companies with earnings growth in the quarter, half of them reported growth rates in the double-digit range.

Also somewhat encouraging was that the average earnings decrease of 26% for the first quarter was less than the 29% year-to-year decline registered in the previous quarter. And although sales were up just 3% in the first quarter this year compared with a year earlier, that's better than the no-growth situation of the previous quarter.

In addition, first-quarter earnings for the 30 major companies increased an average of almost 26% over fourth-quarter 1989, and sales

Earnings decline for most oil companies

	FIRST-QUARTER 1990					
	Sales	Earnings[a]	Change from 1989		Profit margin[b]	
	($ millions)		Sales	Earnings	1990	1989
OIL AND GAS COMPANIES						
American Petrofina	$ 896.3	$ 26.2	25%	−46%	2.9%	6.8%
Amoco	7,129.0	466.0	9	2	6.5	7.0
Chevron	9,300.0	473.0	21	51	5.1	4.1
Exxon	26,713.0	1280.0	20	0	4.8	5.7
Kerr-McGee	811.8	27.1	13	−20	3.3	4.7
Mobil	14,908.0	400.0	6	−7	2.7	3.1
Occidental Petroleum	5,159.0	108.0	0	61	2.1	1.3
Shell Oil	5,754.0	203.0	11	−44	3.5	7.0
Sun Co.	3,110.0	71.0	17	−12	2.3	3.1
Texaco	9,156.0	328.0	−5	−24	3.6	4.5
Unocal	2,643.0	77.0	1	−13	2.9	3.3
TOTAL	**$85,580.1**	**$ 3459.3**	**11%**	**−3%**	**4.0%**	**4.6%**
DIVERSIFIED MANUFACTURERS						
Allied-Signal	$ 3,055.0	$ 129.0	4%	2%	4.2%	4.3%
Borden	1,892.5	63.1	4	7	3.3	3.2
Du Pont	9,404.0	615.0	8	−14	6.5	8.3
Eastman Kodak	4,111.0	199.0	−2	−6	4.8	5.0
Engelhard	658.5	14.8	12	3	2.2	2.4
FMC	813.5	38.0	−3	12	4.7	4.1
Ferro Corp.	279.7	6.0	3	−51	2.1	4.6
3M	3,164.0	335.0	5	5	10.6	10.5
PPG Industries	1,478.0	125.3	1	−3	8.5	8.9
Tenneco	3,602.0	134.0	9	23	3.7	3.3
Vulcan Materials	232.0	18.7	7	19	8.0	7.2
TOTAL	**$28,690.2**	**$ 1677.8**	**5%**	**−4%**	**5.8%**	**6.4%**
PHARMACEUTICAL COMPANIES						
A. H. Robins	$ 1,438.4	$ 225.0	11%	14%	15.6%	15.3%
American Home Products	1,813.4	314.5	4	12	17.3	16.0
Baxter International	1,903.0	−383.0[c]	7	def	def	5.7
Bristol Myers-Squibb	2,457.7	409.1	9	19	16.6	15.2
Merck	1,758.4	403.8	12	19	23.0	21.7
Pfizer	1,482.0	251.9	3	5	17.0	16.8
Rorer Group	277.7	11.1	15	14	4.0	4.1
Shering-Plough	865.1	150.4	4	20	17.4	15.1
Upjohn	772.9	114.3	4	10	14.8	14.0
Warner Lambert	1,100.0	120.3	8	19	10.9	9.9
TOTAL	**$13,868.7**	**$ 1617.3**	**7%**	**−12%**	**11.7%**	**14.3%**

a Earnings from continuing operations excluding significant nonrecurring and extraordinary items. b Earnings as a percentage of sales. c Includes nonrecurring item.

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 21 oil and diversified companies, each with more than $200 million in annual chemical sales, plus 10 pharmaceutical companies.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

rose slightly less than 8%. And first-quarter profitability of 7.3% was up substantially from 6.2% for the same companies in the fourth quarter of 1989. Although quarter-to-quarter comparisons can be affected by seasonal fluctuations—for instance, the first quarter is historically better than the preceding fourth quarter—this is much improved from the 6% sales increase and 15% earnings increase recorded between the comparable quarters of 1988 and 1989. Profit margins rose to 10.1% in the first quarter of 1989 from 9.3% in fourth-quarter 1988.

Chemical company earnings, however, had the largest drop of the industry groups surveyed by C&EN. At 10 pharmaceutical firms, combined earnings fell 12% from last year's first quarter to $1.62 billion on a sales increase of 7% to almost $13.9 billion. This is deceptive, however, since these results include a huge nonrecurring charge at Baxter International that accounted for all of the earnings decline at these 10 firms. Profit margins for the drug companies averaged 11.7%, down from 14.3% in the first quarter of 1989.

For 11 diversified manufacturers that produce chemicals, combined earnings fell 4% in the quarter to $1.68 billion on a 5% sales increase to $28.7 billion. Profitability for these firms averaged 5.8% for the quarter, down from an average of 6.4% in the same period of 1989.

For 11 petroleum and gas companies, combined first-quarter earnings fell 3% from the same period last year to $3.46 billion on a sales increase of 11% to $85.6 billion. This caused profit margins to decline to an average of 4.0% in the first quarter this year from 4.6% in the same period in 1989. Oil company results for chemical operations further underscored the weakness of commodity chemicals in the first quarter.

For eight of the oil firms that report chemical earnings—Amoco, Chevron, Exxon, Mobil, Occidental, Shell, Texaco, and Unocal—these results declined 48% to a total of $773 million in the first quarter. The decline was headed by Texaco's 83% drop to $16 million. This was followed by declines of 63% to $6 million at Unocal; 56% to $98 million at Shell; 55% to $181 million at Exxon; 54% to $98 million at Mobil; 49% to $80 million at Amoco; 34% to $186 million at Occidental; and 6% to $123 million at Chevron. Chevron, however, says that chemical earnings for the first quarter of this year include some one-time benefits from licensing arrangements, stemming from the restructuring of the firm's agricultural chemical operations. Otherwise, earnings declined on sharply lower prices for aromatic and olefin commodity chemicals.

Among the chemical companies, the weaker commodity chemical prices and volumes were cited by Union Carbide and Dow, among others.

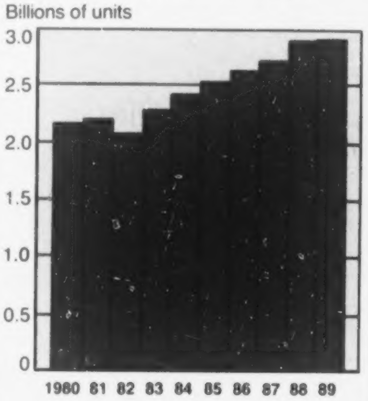
For the remainder of the year, companies are fairly optimistic, given the circumstances. At Dow, president and chief executive officer Frank P. Popoff states that 1990 will not be a record year for earnings, but that the company will post "strong, sustainable results."

Monsanto's chairman, Richard J. Mahoney, says, "While earnings were down from the same period last year, results were affected by seasonal timing shifts in our agricultural markets and slow business conditions in automotive markets. Nevertheless, we're off to a good start toward another record year for Monsanto."

At Rohm & Haas, chairman J. Lawrence Wilson says the company's performance in the first quarter confirms management's belief that its full-year operating earnings will be roughly equivalent to those of 1989. □

Growth streak ends for aerosol industry

Aerosol production was essentially flat in 1989



Source: Chemical Specialties Manufacturers Association

Aerosol production in the U.S. leveled off last year, according to the latest annual pressurized products survey from the Chemical Specialties Manufacturers Association. At CSMA's midyear meeting in Chicago, Thomas E. Moloney, director of marketing for American-National Can Co., revealed that an estimated 2.91 billion container units were filled in 1989, just about the same as in 1988. That figure confirmed predictions of a slowdown after six consecutive years of healthy growth (C&EN, April 23, page 35).

Officially, there was a small increase last year of just under 0.2% from 1988 to 2.912 billion units. The survey process is inherently uncertain, however. For example, although questionnaires were sent to 221 companies with filling lines in the U.S. and Puerto Rico, only 127 of those companies responded (compared with 151 out of 217 in 1988). The survey committee extrapolates from those responses, guided in part by production figures from container and valve manufacturers. So, given the uncertainties, it's fair to say that 1989 was a flat year for aerosols.

The relatively poor showing in 1989 is attributable mostly to a sharp drop in the personal products category. The committee estimates that 1.02 billion units of personal care products of all types were filled in 1989, down 7.7% from 1988. All major subcategories, including deodorants, hairsprays, and shaving lathers, showed declines. However, personal products continued to be the largest product category, representing about 35% of the total (compared with about 38% in 1988).

In contrast, most other major categories showed respectable growth. For example, household products, the second largest category, showed a 4.6% increase to 680 million units. Reported fillings of one subcategory—room deodorants and disinfectants—increased about 30%. Overall, the category accounted for about 23% of the total.

The third-place automotive and industrial products category, representing about 16% of the total, continued to show strong growth. Fillings increased 8.0% to 475 million units. Reported fillings of automotive cleaners of various kinds roughly doubled, to more than 31 million units. The lubricants and refrigerants subcategories also showed healthy gains.

Paints and finishes continued in fourth place. The 350 million units filled in that category accounted for about 12% of the total and represented a 5.7% increase from 1988.

The fifth-place category, insect sprays, accounted for 197 million units (about 7% of the total), up 3.7% from 1988. Food products (including pan sprays), in sixth place with 6% of the total, showed the largest percentage gain among the categories, a 12% rise to 175 million units.

The smallest category, animal products, was flat. An estimated 8 million units were filled, the same as in 1988.

However, in the miscellaneous category, the number of units filled, at 12 million units, was down 60%. The steep decline is primarily a result of refined classification procedures, with formerly "miscellaneous" products now included in other categories.

Ward Worthy

Sagging chlorine use crimps caustic soda supply

Earl V. Anderson
C&EN Northeast News Bureau

Over the next few years, demand for caustic soda will increase at a slightly higher rate than chlorine demand. For caustic soda consumers, this means a few more years of coping with caustic shortages. For chlor-alkali producers, it means finding new customers for chlorine so that caustic output will not be restrained by sagging chlorine production.

This, says Jack R. Clinton, will be the major challenge facing the chlor-alkali industry as chlorine demand in the all-important pulp and paper market declines. Unfortunately, says Clinton, who is business director for liquid caustic soda for Occidental Chemical, Dallas, the industry has only a few options available that will allow it to replace chlorine markets that are under increasing environmental pressure. The best option, he says, is tied to the fortunes of polyvinyl chloride.

Chlorine demand in pulp and paper will slip rapidly . . .

Market	% change per year through 1994
Pulp & paper	−8.6%
Inorganics	1.1
Titanium dioxide	3.4
Water treatment	0
Epichlorohydrin	2.0
Propylene oxide	2.7
Chlorinated ethanes	2.8
Chlorinated methanes	1.4
Export[a]	6.8
Vinyl chloride	4.3
Miscellaneous	0

. . . while petroleum will set the pace for caustic markets

Market	% change per year through 1994
Petroleum	3.5%
Water treatment	2.0
Soaps & detergents	1.5
Textiles	0.5
Alumina	1.0
Pulp & paper	0.6
Inorganics	1.5
Other organics	2.0
Miscellaneous	1.5

[a] As ethylene dichloride. **Source:** Occidental Chemical

Clinton told a recent meeting of the Chemical Marketing Research Association in New York City that the situation has changed dramatically in the chlor-alkali industry since 1986. Then, he says, large inventories of caustic soda were built up throughout the world. Much of this material was sold at prices one fourth what they are today.

Since then, the chlor-alkali industry has operated almost at full capacity. Nevertheless, says Clinton, all caustic output has been consumed and the huge caustic inventory has disappeared. What's more, in those four years the price of caustic has gone up fourfold.

Based on these trends and projected chlorine production, Clinton says caustic demand is outstripping available supply. And he expects this trend to continue over the next several years.

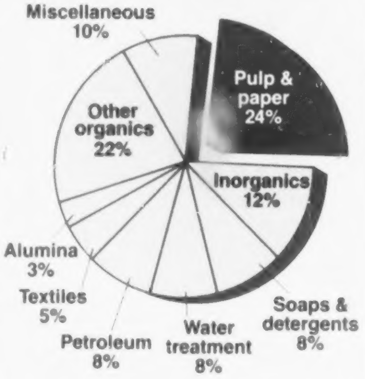
So serious is the problem that the industry is looking into the possibility of making caustic soda from sodium carbonate. Around the turn of the century, this was the preferred method of making caustic, and it remained the preferred method until electrolysis of salt replaced it.

Now, several studies are under way to evaluate the possibilities. But, he says, it remains to be seen whether the economics are attractive enough or whether caustic-from-sodium carbonate projects are even necessary over the long term.

Trying to keep chlorine and caustic production in balance with their respective demands has always been a problem for the chlor-alkali industry. A newer problem is that the industry is becoming much more global in its outlook.

There was a time, and not too long ago, says Clinton, when companies in the chlor-alkali industry could survive by looking at their own geographic—even regional—areas. This was especially true in the U.S.

Pulp and paper take the biggest share of caustic



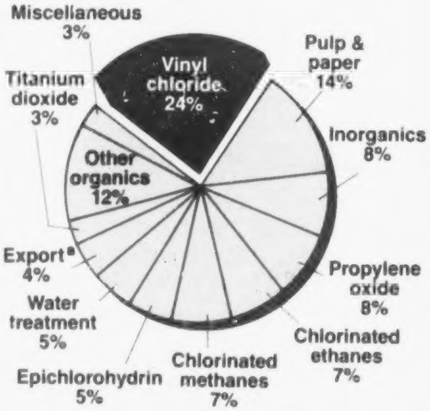
Total 1989 consumption = 12.3 million tons

Source: Occidental Chemical

But "this is a mind-set that must change—and change fast," says Clinton. To deal with its challenges, the U.S. chlor-alkali industry must adopt a global view.

There's little doubt that chlor-alkali producers are part of a global industry. World chlorine production last year was 36.7 million metric tons, with only about a third of it produced in North America.

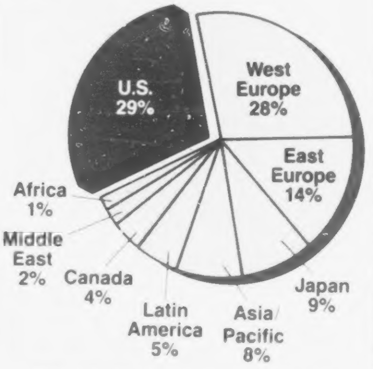
Vinyl chloride is chlorine's largest market



Total 1989 consumption = 12.1 million tons

[a] As ethylene dichloride. **Source:** Occidental Chemical

U.S. produces nearly 30% of world's chlorine



World chlorine production in 1989 = 36.7 million metric tons

Source: Occidental Chemical

Western Europe is a close second, accounting for 28% of chlorine output last year, and East Europe is a distant third with 15% of the total. However, Clinton notes that either of the two largest U.S. producers—Dow Chemical and Occidental Chemical (OxyChem)—has capacity nearly equal to the total of all producers in either Japan or West Germany.

These two companies have nearly half the total U.S. capacity. The remainder is split among almost two dozen other companies. Some of these producers operate on a national, and even an international, basis. But others, Clinton says, limit themselves to local regions within the U.S. and have a very narrow customer base.

Worldwide, chlorine producers operated at about 87% of nameplate capacity last year. In the U.S., operating rates were slightly higher—closer to 90%. Historically, these operating rates are high, but Clinton doesn't expect them to change much over the next three to four years.

Since 1982, nearly 7500 tons per day of chlor-alkali capacity has been permanently shut down. Over the same time span, 2360 tons per day of capacity was added. The net result: a loss of more than 5000 tons per day of capacity, roughly equivalent to 14% of peak 1982 installed capacity.

According to the Chlorine Institute, Clinton says, almost 2000 tons per day of capacity are idle in the U.S., but are viable. The institute estimates that operating capacity of the U.S. chlor-alkali industry now amounts to about 12.5 million tons per year.

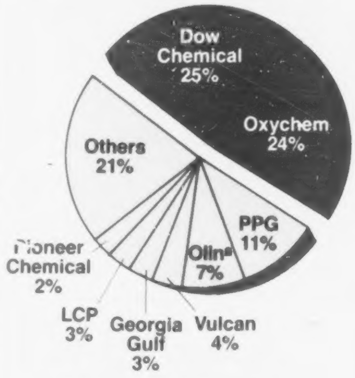
In the U.S., nearly one fourth of all the chlorine consumed goes into vinyl chloride. It is by far chlorine's largest market. Second place goes to pulp and paper, which accounts for 14% of chlorine demand. The remainder of the chlorine goes into many diverse, and much smaller markets. But it has been the strength of the vinyl chloride and pulp and paper markets, says Clinton, that has driven U.S. chlorine demand for the past few years.

That's about to change. Environmental concerns will put a crimp in some chlorine uses, such as chlorofluorocarbons (CFCs), solvents, and especially pulp and paper. Clinton estimates that chlorine demand in the pulp and paper industry will decline about 8.6% per year through 1994.

Last year, pulp and paper consumed 1.8 million tons of chlorine. By 1994, that volume will fall to 1.1 million tons. That's a hefty 700,000 tons, or almost 40% decline.

Meanwhile, concerns about possible ozone depletion also will adversely affect chlorine demand. Some CFCs are being phased out. Others are being reformulated using less, and in some cases no, chlorine.

Dow, Oxychem dominate U.S. chlor-alkali capacity



1990 nameplate capacity = 13.1 million tons

a Includes 50% of Niachlor's capacity.
Source: Occidental Chemical

To appreciate the impact these developments may have on chlorine, Clinton notes that about 300,000 tons of chlorine consumption would be lost if 1,1,1-trichloroethane output were halted by legislative or regulatory action.

Obviously, chlorine marketers face some tough problems. But Clinton believes these potential losses will be more than offset by growth in the ethylene dichloride-vinyl chloride-polyvinyl chloride chain. These products will have the greatest impact on world chlorine demand. Chlorine demand for this market probably will increase 4.3% annually. But Clinton thinks that in the Far East the growth will be much more rapid.

Other fast growing chlorine markets include titanium dioxide and isocyanates. Along with vinyl chloride, these markets are expected to support about a 1% per year growth in chlorine demand through 1994 in the U.S. Globally, growth will be a little higher—about 1.5 to 2.0%.

Caustic soda is a different story. Pulp and paper is caustic's largest market—about 24% of the total. But, unlike chlorine, caustic demand in pulp and paper is growing, albeit slowly. The fastest growing markets for caustic will be petroleum (3% annually) and water treatment (2% annually). Together these outlets will give caustic markets overall annual growth rates of 1.5% in the U.S. and between 2 and 2.5% worldwide. Both are slightly higher than chlorine's growth rates.

In addition to pulp and paper, such markets as bleach, alumina, propylene oxide, and general chemicals will be the driving forces behind caustic demand, says Clinton. Export demand, he adds, will put additional pressure on producers' ability to supply enough material.

Between now and 1994, Clinton expects chlorine-caustic plants to operate between 92 and 96% of capacity. This estimate, however, does not take into account any plant rationalization that may take place as chlorine demand dips. During the first quarter of 1990, operating rates were in the "mid-90% range," says Clinton. He pegs chlorine production this year at only slightly higher than last year's 11.9 million tons. ☐

Thermoplastic color concentrates face challenges

The companies that supply thermoplastic color concentrates to plastics processors have enjoyed a strong run during the second half of the 1980s. Sales have increased from $675 million in 1985 to $875 million last year—a 6.7% per year growth.

The outlook for the first half of the 1990s looks bright, too, says Benjamin D. Berkman, vice president of PMS Consolidated, Coral Springs, Fla. Sales of thermoplastic color concentrates are expected to increase to $1.14 billion by 1995. But this means that the annual growth in sales will taper off to about 4.5%.

More importantly, it implies that producers of thermoplastic color concentrates will have to cope with several critical issues and challenges if they hope to remain in business. Among them:

- Regulatory issues that will shrink the color "palette" for plastics applications.
- Cost of complying with environmental regulations.
- Critical supply of key raw materials.
- Proliferation of specifically tailored new and/or modified polymers.
- Plastics processors' continued conversion from precolored resin to color concentrates.

Despite these problems, Berkman told a recent meeting of the Chemical Marketing Research Association in New York City, demand for plastic materials is far higher now than could reasonably have been expected at the beginning of the eighties. The problems that polymer producers and plastics processors have in handling dust and potentially hazardous pigments and chemicals have provided color concentrate producers with a strong and sustained period of growth.

U.S. output of these thermoplastic color concentrates has increased from 338 million lb in 1980 to 500 million lb in 1989. Growth in production has perked up from 3.2% annually in the early 1980s to 5.4% per year in the second half of the decade. Berkman defines a thermoplastic color concentrate as a plastic compound that contains a high concentration (greater than 20%) of one or more pigments predispersed in a carrier and supplied in pellet form. They are used with natural (uncolored) resins to achieve the desired color when the mix of natural resin and color concentrate is converted into a final product.

Berkman credits the healthy economic conditions that persisted in the U.S. throughout most of the eighties for much of this growth. These conditions sustained a high demand for plastics and, consequently, a high demand for color concentrates.

Demand was also helped by the increasing use of color in many plastics products earmarked for the consumer market. While this demand for more color was taking place, many plastics compounders were moving away from dry pigments, favoring precolored resins instead.

Meanwhile, color concentrates have experienced an almost explosive growth in engineering thermoplastics. Demand for engineering resins is expected to increase from $35.8 million in 1985 to $54 million this year, then mushroom to a hefty $83 million by 1995. Although that still will leave the engineering resin market far behind the commodity resins, such as low- and high-density polyethylene, polypropylene, polyvinyl chloride, and polystyrene, it still represents a sizable and growing outlet.

This growth in engineering resins has been spurred by two changes in coloring nylon, says Berkman. First is the growing preference for concentrates rather than dry pigments to precolor nylon. And more color concentrate is being used to color nylon fiber before it is made into carpet or fabric. In this instance, color concentrate is replacing traditional textile dyeing in yarn and/or piece goods.

The packaging industry has given a big boost to the use of color concentrates in high-density polyethylene (HDPE). As color became more important—either to differentiate among products or to attract consumer attention—concentrate use in HDPE has increased substantially. But the cost of color concentrates has risen faster than volume.

Low-density polyethylene is the largest use of thermoplastic color concentrates . . .

$ Millions	1985	1990[a]	1995[a]
High-density polyethylene	115.5	162.0	204.0
Low-density polyethylene	166.3	209.0	250.0
Polypropylene	88.0	126.0	162.0
Polyvinyl chloride	136.8	176.0	215.0
Acrylonitrile-butadiene-styrene	20.0	29.0	40.0
Polystyrene	80.4	100.0	128.0
Polyethylene terephthalate	11.0	15.0	21.0
Engineering resins	35.8	54.0	83.0
Other	21.2	29.0	36.0
TOTAL	675.0	900.0	1139.0

. . . and packaging is their biggest single market

$ Millions	1985	1990[a]	1995[a]
Building & construction	105.2	126.0	149.0
Consumer products	106.0	134.0	166.0
Electrical and electronic	63.8	83.0	109.0
Packaging	297.4	411.0	531.0
Transportation	57.8	92.0	121.0
Furniture & furnishings	44.8	54.0	63.0
TOTAL	675.0	900.0	1139.0

[a] PMS Consolidated estimates. Source: PMS Consolidated

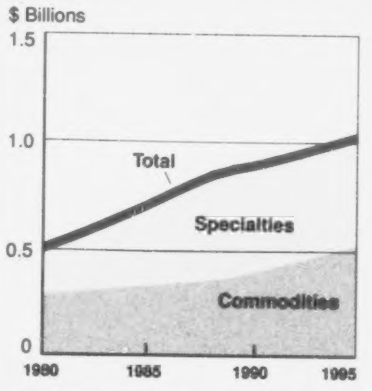
In addition to HDPE, compounders have moved away from dry pigments toward color concentrates to precolor low-density polyethylene (LDPE) and acrylonitrile-butadiene-styrene (ABS) resins. The driving force: concern about safety and health regulations. In particular, color concentrates have become increasingly popular in in-plant coloring of ABS-molded auto parts.

Berkman believes that color concentrates have a lot of potential in the transportation market. Interior plastic trim in cars and small trucks is almost totally colored with concentrates. And interior carpet and fabric will become a rapidly growing market as automotive fabric manufacturers turn to pigmented fibers to meet new specifications for fade resistance. However, Berkman says the large, long-range potential for color concentrates in automotive applications parallels plastics' penetration into exterior body parts. This, in turn, will be driven by car companies' desire to eliminate the need for painting.

Despite the prospects for growth in thermoplastic color concentrates demand, producers will find several rocks in the road to prosperity. One of those rocks is the regulatory issues that threaten to shrink the color palette in plastics.

Berkman says the initial thrust—to eliminate lead-based pigments—has now blossomed into a full-scale drive to eliminate all heavy-metal pigments for most plastics products, and to eliminate them as hazardous raw materials from plants such as those that produce color concentrates. And the list of usable organic pigments is getting shorter as data show that some of them degrade into hazardous materials when exposed to elevated temperatures and mechanical shear in plastics processing plants.

Sales of thermoplastic color concentrates will slow



Source: PMS Consolidated

It may be possible to formulate around some of these problems, says Berkman. Nevertheless, he points out that some strong, vibrant color effects that are now popular in many consumer products will be duplicated only at greater expense or not at all.

Another problem facing color concentrates producers is the high cost of complying with Occupational Safety & Health Administration and Environmental Protection Agency regulations governing worker exposure to dust and other potentially hazardous materials, as well as with regulations governing disposal of plant effluent and solid waste. In fact, Berkman wonders if some of the smaller concentrates companies will be able to shoulder these costs and whether they can afford to clean up contaminated land surrounding older units. He thinks there's a good chance that the number of small, independent producers will shrink. Some may consolidate.

Raw material supply is also becoming a problem for color concentrates companies. As heavy-metal pigments are eliminated, and the color concentrates industry depends more on organic and mixed-metal oxide pigments, it will compete more heavily with the paint and coatings industry for these materials. Berkman also suspects that foreign pigments producers may enter the U.S. color concentrates industry, either through acquisition or with a new facility.

As new polymeric alloys proliferate, and as changes are made in traditional polymers to meet new performance standards in niche markets, Berkman expects that color concentrates producers will find themselves in the "interesting, but possibly precarious position" between the polymer producer and the plastics processor. In the early stages, he explains, the concentrate company will be asked to produce colorants for new polymeric materials so that they can be marketed as precolor compounds.

Because of the unique characteristics of the new polymers, traditional colorant formulations will not do. Color concentrates producers will have to increase their R&D. Then, as the new polymers mature and as plastics processors convert from precolor compound to in-house coloring of the natural resin, the color concentrates company will face a new set of problems. The plastics processor, says Berkman, will look to its color concentrates supplier for the polymer technology, colorant know-how, and processing experience that it needs to produce a high-quality colored plastic part at the lowest possible cost.

Earl Anderson

Taiwan's chemical industry looks overseas

Taiwan has developed a successful integrated petrochemical industry over the past three decades by back-integrating from finished product to raw material and, in some cases, to basic feedstock. Now the industry must face several problems that could put a crimp in the fabulous growth rates to which it has grown accustomed.

One problem is that Taiwan doesn't have enough ethylene or aromatics capacity to satisfy demand from existing derivatives plants, much less those that will be built over the next few years. But land suitable for building new petrochemical complexes in Taiwan is becoming increasingly scarce and expensive. Environmentalists' opposition to new plants is mounting. And labor shortages have developed.

One way Taiwanese chemical companies are coping with these problems is to set up operations outside Taiwan, says Wenent P. Pan, director of Chinese Petroleum Corp.'s corporate planning division. Taiwan's capital investment in Southeast Asia alone, which was only $400 million in 1987, totaled more than $4 billion over the past two years.

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Goodyear photo

Rubber Chemicals Industry Strong, Slowly Growing Despite Changes

Stephen Stinson,
C&EN Northeast News Bureau

In the past five years, the U.S. rubber-processing chemicals industry has been turned upside down. Many of the supplier companies have suffered raids, mergers, restructurings, and breakups. And the domestic tire industry, which uses the largest amounts of these chemicals, has likewise changed in ways that reduced the number of producers and left all but one foreign-owned.

But though these changes have been wrenching, they may have left both industries stronger. A reduction in the number of chemical suppliers has eased competition, enabling the survivors to earn respectable profits in the very slowly growing market. In fact, the staff of Uniroyal Chemical Co., who went through a hostile raid, friendly takeover, and management buyout, found time to increase their share of the U.S. rubber processing chemicals market from 8% to 18%.

And the conversion of the U.S. tire industry to multinational, if foreign, ownership has enabled globally sited chemical firms to centralize marketing efforts.

Continuing pressures to protect the environment have shifted investment from development of new products to cleaning up plants and improving processes. Many rubber-processing chemicals are based on odorous sulfur compounds and aromatic amines. During these eventful five years, new funds have gone to upgrade existing plants, build new plants around environmentally advanced designs, and develop cleaner routes to existing chemicals.

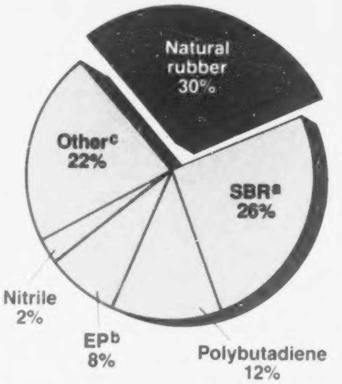
Further impetus to improve plants and processes comes from the rubber industry, whose managers want tighter specifications and narrower variation in processing chemicals. For chemical suppliers, these past five years have seen the introduction of statistical process control, intensified lot-to-lot testing, and monitoring of their processes by their rubber company customers.

What efforts there are to develop new chemicals stem from recent concern over carcinogenic nitrosamines. Though only West Germany has set numerical limits on these concentrations to date, U.S. chemical producers and rubber fabricators are gearing up for possible regulations in this country.

Certain accelerators of vulcanization are susceptible to reaction with airborne nitrogen oxides, and, via nitrosation, become nitrosamines. At issue are not only nitrosamine concentrations in rubber factory air but also in tire warehouses and car trunks where the spare tire sits. The solution may be switching to other existing accelerators or development of new ones that lack susceptibility to nitrosation.

Thus, though the next five years may lack the high drama of the past five, the issues of cleaner plants and processes, higher chemical product quality, and nitrosamines will keep U.S. rubber-processing chemical producers very busy.

Natural rubber holds a 30% share of consumption



1989 total U.S. rubber consumption = 6.6 billion lb

a Styrene-butadiene rubber. b Ethylene-propylene rubber. c Includes butyl, polyisoprene, polychloroprene, and silicone rubbers. **Source:** Rubber Manufacturers Association

C&EN estimates the domestic rubber industry will use 245 million lb of organic processing chemicals in 1990, worth $395 million, compared with 235 million lb in 1989 at a value of $380 million. Of 1990 consumption, 61% by weight will be antioxidants and antiozonants, 34% will be vulcanization accelerators, and 5% will be others such as peptizers and blowing agents.

One gauge of the volume of such a market is that if all the 200-odd substances rubber compounders use to make vulcanized rubber were produced as one substance, its volume would be only one quarter of the amount needed to make it number 50 on C&EN's list of the Top 50 chemicals. And if one firm produced that substance as its sole activity, the dollar value would make that firm only number 84 on C&EN's list of the Top 100 chemical producers.

Yet about 23 U.S. producers plus dozens of distributors for American and foreign companies vie for a share of this market. Of these firms, Monsanto, Uniroyal, Mobay, and Goodyear sell 85% of U.S. needs.

Antidegradants make up the largest class of rubber-processing chemicals

	U.S. consumption, millions of lb					
Type	**1986**	**1987**	**1988**	**1989**	**1990**	**1995**
Antidegradants[a]	136.3	144.2	148.4	144.5	150.8	164.9
Accelerators[b]	74.7	79.1	81.4	79.2	82.6	90.4
Miscellaneous[c]	11.1	11.7	12.0	11.7	12.2	13.4
TOTAL	**222.1**	**235.0**	**241.8**	**235.4**	**245.6**	**268.7**

a Antidegradants include antioxidants and antiozonants. b This category includes vulcanization accelerators, retarders, and organic sulfur donors. c Miscellaneous chemicals include peptizers and blowing agents. **Source:** C&EN estimates

Although 1990 consumption of rubber-processing chemicals will probably be 245 million lb, it is almost impossible to estimate U.S. production for foreign trade. This is because the U.S. International Trade Commission stopped tabulating imports in 1983, and the Bureau of the Census ceased publishing figures on exports in 1988.

The U.S. ITC does publish annual reports of production and sales of rubber-processing chemicals, but most industry analysts discount these as unreliable. This may be because some rubber antioxidants are also gasoline, lubricating oil, and plastics additives. And some derivatives of dithiocarbamic acid are fungicides as well as vulcanization accelerators.

The U.S. ITC reports domestic production of rubber-processing chemicals was 318 million lb in 1989. This seems very high in view of the tight production capacity in this country, possible imports in the neighborhood of 10 million lb, and the consequent inability to export almost 100 million lb.

C&EN estimates that in 1989, Monsanto Chemical Co. of St. Louis produced 92 million lb of rubber-processing chemicals for the domestic market. The company sold 68 million lb of this to tire makers, and 24 million lb was distributed to the nontire rubber industry by Harwick Chemical Corp., Akron, Ohio.

Uniroyal of Middlebury, Conn., made and sold 42 million lb in the U.S. alone in 1989. Mobay Chemical Corp., Pittsburgh, Pa., produced and imported 38 million lb, selling most of that itself and marketing perhaps 5 million lb through distributors.

Akron-based Goodyear Tire & Rubber Co., a tire maker, and B. F. Goodrich, formerly a tire maker, both produce rubber-processing chemicals and sell them in a three-way relationship with R. T. Vanderbilt Co., Norwalk, Conn., which is itself a chemicals producer. According to the agreement, Goodyear sells its antioxidants and antiozonants (perhaps 14 million lb in 1989) through its own sales force and distributes its accelerators (possibly 10 million lb) through Vanderbilt. Goodrich distributes its antioxidants and antiozonants (perhaps 5 million lb in 1989) through Vanderbilt and its accelerators (possibly 7 million lb) through Akron Chemical Co. For its part, Vanderbilt may have made 7 million lb of rubber-processing chemicals in 1989.

A slowly but steadily growing presence in rubber-processing chemicals is Akzo Chemicals of Chicago, a subsidiary of Akzo in Arnhem, the Netherlands. Its 1989 sales may have been a little less than 10 million lb in the U.S.

Akzo Chemicals has owned the former Noury Chemicals of Burt, N.Y., makers of organic peroxides, since 1972. Though used mostly as initiators of polymerization and curing of unsaturated polyesters, some peroxides are vulcanizing agents for specialty rubbers.

Akzo acquired the insoluble sulfur business of the former Stauffer Chemical Co. from ICI in 1987, and also acquired a French rubber chemical company called Vulnax. In 1989, it picked up the accelerator-chemicals plant of Pennwalt Italia in Termoli.

Most recently the company has announced a $30 million, 25 million lb-per-year plant to make 2-mercaptobenzothiazole accelerator in LeMoyne, Ala., due on stream late in 1991. In line with current environmental concerns, the plant will use a process that cuts by-products by 50%. Of the process, which seems to involve the usual reaction of aniline, carbon disulfide, and sulfur, company spokesmen say only that it involves a catalytic oxidation.

The beginning of the new era for the U.S. tire industry and its processing chemicals suppliers began in 1985 when Uniroyal, which was then a tire, chemical, and plastics company, attracted an unwanted

What rubber-processing chemicals are

The rubber-processing chemicals described in this report are the 200-odd organic substances that rubber compounders use to make vulcanized rubber products. With the exception of such goods as adhesives and crepe rubber shoe soles, raw, unvulcanized rubber has no commercial uses.

This report covers accelerators, used to speed the crosslinking reaction with sulfur; activators, used to potentiate the accelerators (sometimes called secondary accelerators); retarders, used to delay vulcanization; organic sulfur donors and peroxides, used as vulcanizing agents; peptizers, used to reduce rubber polymer viscosity; and antioxidants and antiozonants (collectively called antidegradants), used to protect rubber during processing and afterward in use. Rubber compounders use an average of 4.5 lb of these rubber-processing chemicals per 100 lb of rubber.

Organic compounds not covered in this report include mercaptans that regulate polymerization of monomers to synthetic rubber, those peroxides that initiate such polymerization, fatty acid activators, and various oils and asphalt used as physical plasticizers and extenders.

Among inorganic compounds excluded from this report are elemental sulfur as a vulcanizing agent, zinc oxide and other oxide activators, carbon black, silica, and clay reinforcements and fillers.

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takeover bid from New York City investor Carl Icahn. To escape, Uniroyal's management agreed to allow the company to be acquired by the New York City investment firm of Clayton & Dubilier.

In 1986, Uniroyal and its new owners agreed with Goodrich to merge their tire-making operations into a joint venture, Uniroyal Goodrich Tire Co. of Akron. Later that year, Uniroyal sold Uniroyal Chemical Co. to a publicly held investment company called Avery. Finally in 1989, Uniroyal Chemical was taken private in a leveraged buyout by its managers, the same group that had not only survived since 1986 but that had made the company thrive.

Meanwhile in 1988, Goodrich sold its share in Uniroyal Goodrich Tire Co. to Clayton & Dubilier, which had retained the other half. Three weeks ago, Clayton & Dubilier completed the sale of the tire company to the French firm, Michelin Group.

Rubber heads for 500th birthday

1495. In perhaps the first mention of rubber in Europe, Michele de Cuneo returns from Columbus' second voyage and writes, in Hispaniola "there are also trees that when cut give milk, of which [the Indians] make something like wax, and we have tried it out."

1521. Hernando Cortés in Mexico sees the Aztecs using a gum from trees to waterproof utensils and make balls for games. Spanish colonists also use the gum for waterproofing, but for the next 300 years it appears in Europe only as balls and other curiosities.

1750. After a 14-year search in South American jungles, engineer François Fresneau discovers the rubber tree, *Hevea brasiliensis*. Astronomer Charles de la Condamine reads Fresneau's paper to the French Academy, using the Indian word caoutchouc, derived from caa (tears) and ochu (wood).

1770. Joseph Priestley writes that the gum makes a good "rubber" to erase pencil marks, but he is probably not the first to use the word.

1819. Inventor Thomas Hancock develops solvent processing, and the manufacture of rubber articles begins in England. Products eventually include the raincoat of Charles Macintosh (1823) and waterproof shoes. Hancock also builds a machine that renders rubber more tractable, thus inventing mastication. But rubber goods are inferior, becoming sticky in summer and brittle in winter.

1839. Charles Goodyear accidentally finds that heat cures a compound of rubber, sulfur, and lead carbonate to a hard, resilient, infusible solid. Hancock discovers the process independently and coins the term vulcanization. Goodyear gets a patent, U.S. 3633, June 15, 1844.

1876. Coffee planter Henry Wickham smuggles 70,000 Hevea nuts out of Brazil, which until now has had a monopoly of world rubber production. The British send 3000 seedlings grown in Kew Gardens to start plantations in Ceylon and Malaya. By 1900, plantings reach 4000 acres in those lands.

1888. Veterinarian John Boyd Dunlop makes pneumatic bicycle tires. Extension of this idea to automobile tires will make the fortunes of both the rubber and auto industries.

1906. Chemist George Oensager at Diamond Rubber Co., Akron, Ohio, discovers that aniline accelerates vulcanization. Though abandoned as too toxic, the compound becomes the first in a long line of organic accelerators in coming decades.

1910. Recent invention of the automobile stimulates production of more than 200 million lb of rubber per year as prices skyrocket to $3.12 per lb. German chemistry professor Carl Dietrich Harries at the University of Kiel finds that sodium catalyzes polymerization of 2,3-dimethylbutadiene to a synthetic "methyl rubber."

1918. By the end of World War I, Germany has produced a total of 5 million lb of methyl rubber.

1927. Chemists at Bayer develop Buna S (butadiene-natrium-styrene) rubber, inspired by work of chemistry professor Karl Ziegler at Heidelberg University. In the U.S., J. C. Patrick tries to make ethylene glycol by hydrolysis of ethylene chloride in alkaline sodium polysulfide solution. He ends up inventing polysulfide rubber instead, and Thiokol Chemical Corp. is founded to produce it in 1929.

1931. Du Pont announces neoprene, a synthetic rubber made from chloroprene, whose commercial synthesis has been developed by Wallace H. Carothers.

1942. Cut off from supplies of natural rubber, the U.S. government orders the planting of 75,000 acres of latex-producing guayule shrub. After World War II, work on guayule will be abandoned. U.S. industry gears up to make various synthetic rubbers and reaches a capacity of 1.5 billion lb per year by 1945.

1950. The U.S. Army takes World War II jeeps out of mothballs for the Korean War but finds the tires have deteriorated. Studies pinpoint ozone as the cause and lead to development of organic antiozonants.

1973. U.S. consumption of natural rubber has bottomed out at 22% of all rubber used. But now the Arab oil embargo and a series of steep rises in olefin prices tilt the balance against synthetic rubber during the decade.

1990. World rubber production reaches 25 billion lb, 37% of it natural. The U.S. consumes 6.4 billion lb, 27% of which is natural rubber. To fabricate this amount of rubber, the U.S. uses 245 million lb of organic rubber-processing chemicals.

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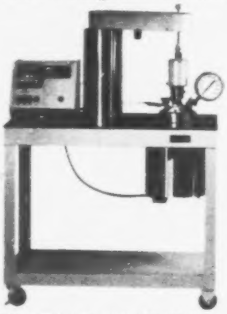

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CIRCLE 22 ON READER SERVICE CARD

In 1986, English investor Sir James M. Goldsmith and the London-based investment company, Hanson Industries, proposed a takeover of Goodyear. The company responded with a vigorous restructuring and a tender offer for its own shares. Also, the state of Ohio passed a series of laws to let Ohio companies force sales of their own shares from selected shareholders in return for other securities, and to finance sales of their own shares to third parties. The English partners then agreed to sell their shares to Goodyear.

Also in 1986, Borg-Warner, Chicago, became the object of a bidding war between Minneapolis investor Irwin L. Jacobs and GAF for a hostile takeover. Among its other activities, Borg-Warner's Morgantown, W.Va., plant produced phosphite ester stabilizers and phenolic antioxidants for rubber.

Though Jacobs dropped out in March 1987, GAF persisted until Borg-Warner's management agreed that the company would be acquired by the investment group, Merrill Lynch Capital Partners, a month later. GE Plastics, a division of General Electric Co., bought the rubber chemicals business along with Borg-Warner's plastics in 1988.

Also in 1988, Pennwalt of Philadelphia came under attack from New York City-based Centaur Partners. Pennwalt's managers spent the year selling off assets, including Pennwalt Italia, to Akzo, in an effort to restructure the company. But Centaur Partners continued, and Elf Aquitaine of France acquired an attenuated Pennwalt in a friendly takeover in 1989 and merged it into its Atochem North America subsidiary. Included in Atochem North America is the former Lucidol Division of Pennwalt, Buffalo, N.Y., which makes organic peroxides.

While these changes were going on in the rubber-processing chemicals industry, the domestic tire and rubber industry also underwent change The upshot has been to leave Goodyear and Cooper Tire & Rubber Co. as the only independent major American rubber companies.

In addition to the Michelin purchase of Uniroyal Goodrich Tire Co. this year, Continental Gummiwerke of West Germany acquired General Tire & Rubber Co. in 1987. Bridgestone of Japan bought Firestone Tire & Rubber Co. in 1988, and in the same year, Pirelli of Italy purchased Armstrong Rubber Co. In 1990, Yokohama Rubber Co. of Japan bought Ohio-based Mohawk Rubber Co.

This worldwide consolidation of rubber and tire production, which industry observers call globalization, is leading also to standardization both in the rubber industry and in the processing chemicals industry that supplies it. For example, Walter J. Cook of Uniroyal Chemical says his company thinks in terms of a world tire.

Cook, who is Uniroyal's vice pres-

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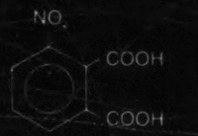

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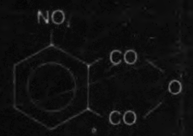

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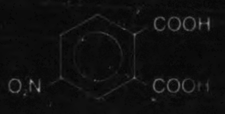
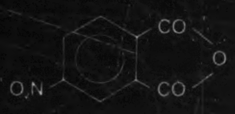


4 - Nitrophthalic acid



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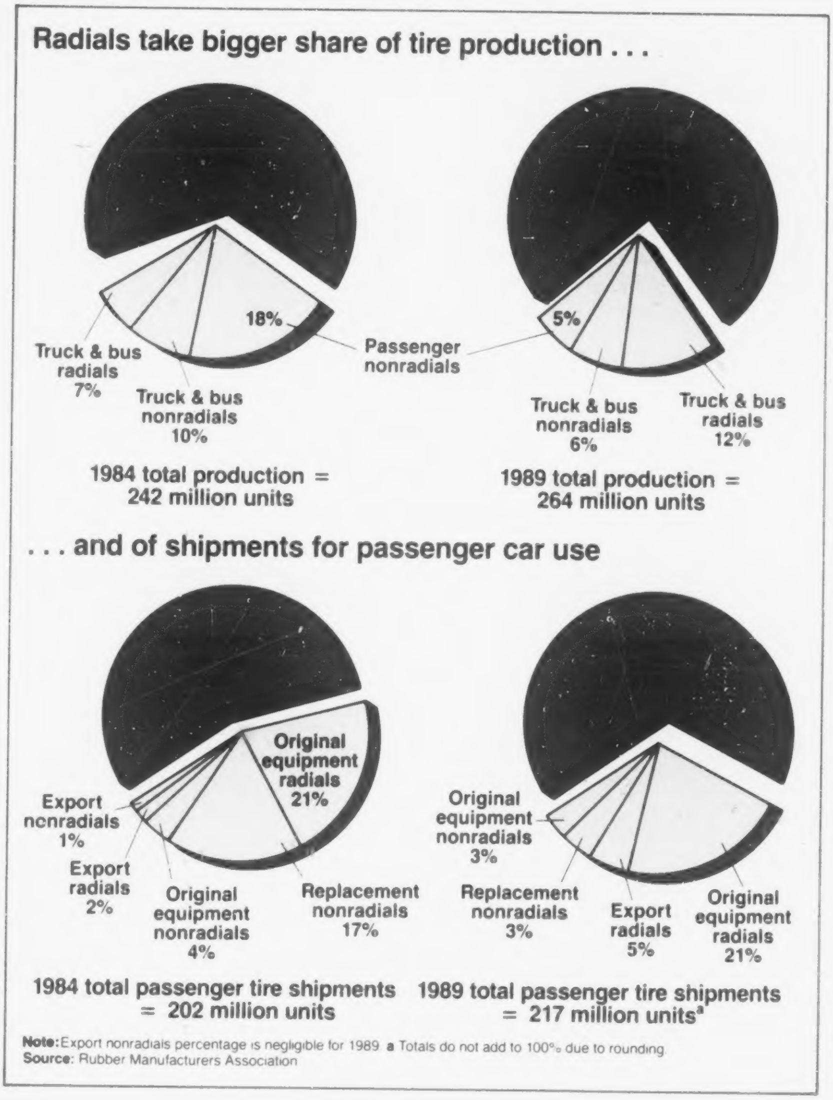

Note: Export nonradials percentage is negligible for 1989. a Totals do not add to 100% due to rounding.
Source: Rubber Manufacturers Association

ident and general manager for chemicals and polymers worldwide, also cites the effects of the relatively recent "transplant" phenomenon. Transplant is the name first given to U.S. production plants of Japanese automakers. But in Cook's parlance, transplants are auto and tire factories of any country in any other country, including those springing up in the Third World.

Cook points out that transplant automakers demand the same high, narrowly standardized quality tires that their parent companies buy for their western production. And transplant tire makers demand the same high, narrowly standardized quality chemicals that their parents use at home. Moreover, tire companies want to be able to ship tires they make in any country to any other country with complete confidence of acceptability.

Thus the same five years that have changed the structure of the rubber processing chemicals industry also have seen the manner of producing and selling these chemicals change. Roger K. Price, who is vice president of Vanderbilt's Rubber Chemicals & Minerals Group, described how the new situation has affected his company.

Nowadays Vanderbilt sends out a certificate of analysis with every chemical shipment to 1700 customer locations. Price contrasts this activity with that of five years ago, when

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Glossary of rubber-processing chemicals terms

Accelerator. Speeds crosslinking of rubber by sulfur. Example: 2,2′-dithiobis-(benzothiazole).

Activator. Renders accelerators more potent. Example: zinc oxide with stearic acid. Alternatively, a secondary accelerator that is an accelerator in its own right but is mostly used with others. Examples: thiurams, dithiocarbamates, and guanidines.

Antidegradant. Inclusive term to denote antioxidants, antiozonants, and stabilizers.

Antioxidant. Protects cured rubber products against oxidative degradation in service. Examples: *N*-isopropyl-*N*′-phenyl-*p*-phenylenediamine, which is also an antiozonant, and octylated diphenylamine, which is not. Antioxidants that protect synthetic rubber during processing are called stabilizers.

Antiozonant. Protects cured rubber products against ozone. Examples: waxes, which migrate to the surface to form a physical barrier, and *N,N*′-bis(1,4-dimethylpentyl)-1,4-phenylenediamine, which protects by chemical reaction.

Blooming. Unwanted migration of such substances as sulfur to rubber surfaces to produce discoloration.

Bonding agent. Enhances adhesion of rubber to fabric or fiber.

Cure. Crosslinking of rubber polymer chains to impart elastomeric properties. Also called vulcanization.

Cure time. Time needed for rubber compounds to reach maximum viscosity or elastic modulus at a given temperature. The sum of the scorch time and crosslinking time.

Hard rubber. Rubber cured with 15 to 40% of added sulfur.

Latex. Water emulsion of rubber polymer, used as is for coatings or dewatered to make solid parts.

Lubricant. Eases flowing of rubber in molding or extrusion.

Mastication. Preliminary physical and

only 10 customer locations demanded such attention. Vanderbilt also compiles quarterly reports for customers of upper and lower limits of various process parameters according to statistical process control so that customers can verify how stable Vanderbilt's processes are.

Demands of the recent quality regime are reflected in the $6 million, 50% expansion of Vanderbilt's chemical plant in Murray, Ky., which opened a year ago. Pneumatic valves and electrical relays have given way to electronic controls. A central computer not only drives programable logic control modules but also accumulates data for statistical process control charts for quality control reports to customers.

One organization that is profiting from the drive for quality and narrow standards is Monsanto Instruments & Equipment, Akron, Ohio. In 1988 the company introduced three microprocessor-controlled instruments and two software packages for data analysis.

The moving die rheometer—MDR 2000—and the oscillating die rheometer—ODR 2000—are each priced at $40,000. The Mooney viscometer MV 2000 sells for $28,000. To enhance capabilities of these, RheoLogic and MooneyLogic are available in many individual configurations for about $10,000 each, a price that includes the recommended IBM PS/2 Model 30 microcomputer to run them. These products join the somewhat older microprocessor-controlled Tensometer 10 ($19,800) and TensiLogic ($10,000).

As Monsanto Instrument's markets and products manager Jack Hanley puts it, "What happened to us from the mid-80s is that we started hearing a lot of noise from the marketplace. Customers wanted more precise results, and customers wanted better productivity from the instruments they were using. And that essentially drove us to the Series 2000."

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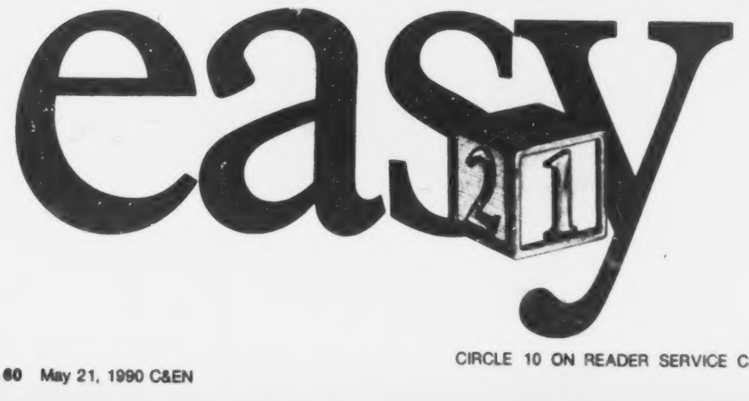

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chemical breakdown, usually of natural rubber, in a mill or mixer to reduce viscosity for further processing.

Peptizer. Promotes chemical breakdown of rubber during mastication. Also called a plasticizer. Example: pentachlorothiophenol.

Phr. Parts per hundred rubber. The number of parts by weight of substance added to 100 parts of rubber.

Plasticizer. A peptizer, oil, or monomeric ester softener or extender. Example: bis(butoxyethoxyethyl) glutarate.

Retarder. Lengthens the amount of time before onset of the curing process. Example: phthalic anhydride. Sulfenamide-type retarders have acquired the separate name of prevulcanization inhibitors. Example: *N*-cyclohexylthiophthalimide.

Reversion. Decrease in rubber elastic modulus or viscosity caused by overworking.

Scorch. Premature curing.

Scorch time. Safety margin of time that a rubber compound can be worked at a given temperature before curing begins.

Soft rubber. Rubber cured with 0.5 to 8% of added sulfur.

Stabilizer. Antioxidant that protects rubber between the polymerization and curing steps. Example: tris(nonylphenyl) phosphite.

Staining. Blue or purple coloration of rubber surfaces owing to oxidation of phenylenediamine-type antioxidants and antiozonants.

Sulfur donor. Organic polysulfide that replaces some elemental sulfur in rubber compounds and promotes curing mostly by monosulfide crosslinks in a process called efficient vulcanization. Example: tetramethyldithiuram disulfide.

Vulcanizing agent. Cures rubber by forming crosslinks among polymer chains. Examples: sulfur, organic peroxides, and phenolic resins.

The more precise results come from microprocessor control, which ensures reproducible heating back up to test temperature. Fast heating minimizes operator variation. The rheometers also measure torque by a new method with greater precision than other instruments. And dynamic calibration comes from use of a torque standard.

The better productivity results from shorter times to do each test. This is because dies are directly heated, the temperature is self-calibrating, calculation of standard data points is automatic, and a new die design eases sample removal.

For the future, Monsanto will capitalize on two growth trends: siting of test instruments on production floors and customers' desires for ro-

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botics for testing. The new instruments have membrane keyboards, which can endure production conditions.

Says Hanley, "We're recognizing that some of our customers have installed our instruments directly in the production environment. This, of course, is a change of philosophy on their part, where they're trying to get the process control more into the process and having the operator of the mixer or the process itself engaged with measuring the quality of the material."

Hanley further declares, "Sometime within the next year we will market a dedicated robot." Users will arrange labeling of samples with bar codes. Controlled by a microcomputer, the robot will read the bar code to get instructions, insert the sample into as well as remove it from the sample chamber, and send the resulting data to the user via the computer.

In addition to building and upgrading plants for better process stability and control, rubber processing chemical firms have striven to improve environmental performance of their processes. Akzo's plant at LeMoyne, Ala., will make 2-mercaptobenzothiazole by a new process that greatly reduces effluent. Carl Clay, manager of the rubber department at Mobay Corp., points out that in 1985, parent Bayer of West Germany, decided to devote future capital spending to include environmental upgrading among other improvements to existing plants worldwide.

Price of Vanderbilt says his company has spent $8 million in environmental improvements to its plant in Bethel, Conn. And Vanderbilt's expansion in Murray, Ky., includes facilities to oxidize all sulfur by-products of its processes to sodium sulfate, which is sold to nearby paper mills.

Although process and plant improvements have taken investment away from new product development, there have been some advances. At Goodyear, for example, Roger Hagstrom says the company has introduced a nonstaining antioxidant that is a reaction product of *p*-nonylphenol, dodecanethiol, and formaldehyde.

Hagstrom, who is director of marketing in Goodyear's Chemical Division, also points to a new polymerizable antioxidant, *N*-(4-phenylaminophenyl)methacrylamide. Using about 1.5%, this compound can be copolymerized into styrene-butadiene, nitrile, polybutadiene, acrylonitrile-butadiene-styrene, or neoprene rubbers; grafted at a 1% level onto these rubbers; or added to these rubbers, either as free acrylamide or as a 38% copolymer with butadiene. When added as free acrylamide, it functions as an antihardening agent by trapping free radicals.

Elsewhere at Goodyear, Hagstrom says the firm may introduce new sulfenamide accelerators. Goodyear closed its Akron rubber-processing chemicals plant in 1985, which took the company out of accelerator types made there. Currently, the only accelerator Goodyear produces is 4-morpholino 2-benzothiazolyl disulfide at Niagara Falls, N.Y.

New product opportunities may also arise in the future to replace accelerators that form carcinogenic nitrosamines. Examples of these types of accelerators are tetramethylthiuram disulfide and *N*-oxydiethylene-2-benzothiazolesulfenamide. These compounds may react with atmospheric nitrogen oxides before use, during vulcanization, or in stored vulcanized rubber products to form nitrosamines.

The solution may be to switch to such existing accelerators as *N-tert*-butyl-, *N*-cyclohexyl-, or *N,N*-dicyclohexyl-2-benzothiazolesulfenamide. Clay of Mobay says Bayer has developed new alternative accelerators. These are experimental compounds still in testing worldwide, however, and Clay adds it is premature to discuss them.

For its part, Akzo has developed tetrabenzylthiuram disulfide. Because of the higher molecular weight of the tetrabenzyl accelerator, it must be used at about 2.3 times by weight when replacing tetramethylthiuram disulfide in order

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R. T. Vanderbilt's Murray Ky., plant has more than 40 miles of pipeline that help maintain a constant flow of chemicals during processing

to furnish the same amount of organic sulfur to develop comparable properties in rubber. This will make use of the tetrabenzyl additive more costly.

Still Akzo scientists are encouraged, because *N*-nitrosodibenzylamine seems not to be carcinogenic. Too, the tetrabenzyl compound itself contains low amounts of that nitrosamine. The concentration of the nitrosamine does not increase during vulcanization. And tetrabenzythiuram disulfide combines lower toxicity (than the tetramethyl derivative) with nonvolatility during storage of rubber products.

In general, U.S. consumption of rubber-processing chemicals rises and falls with the sheer volume of rubber use. Because 60% of rubber goes to make tires, changes in tire-making technology can affect overall patterns of chemical consumption, but only in small ways in comparison with effects of much wider swings in the economy.

Domestic rubber consumption peaked at 7.4 billion lb in 1977, according to the Rubber Manufacturers Association (RMA). After bottoming out at 5.3 billion lb in the long 1979–82 downturn in durable goods, demand only returned to 6.2 billion lb in 1989. The International Institute of Synthetic Rubber Producers (IISRP) has predicted an average annual average increase of 1.5% in North America into the mid-1990s. This could point to use of only 7 billion lb of rubber in the U.S. in 1995.

The smaller changes in domestic use of rubber-processing chemicals in the next five years may be influenced by the continuing trend toward replacement of bias-ply by radial tires, increased production of so-called high-performance, low-profile tires, reversal of the 15-year-old trend toward smaller tire sizes, and the growing number of states that have abolished the 55-mph speed limit.

In the five years from 1984 to 1989, tire production rose to 264 million units from 242 million, according to RMA. During that period, radial tires for passenger cars increased their share to 77% from 65% of all tires produced. And tires for trucks and buses raised their share to 12% from 7% of the total, leading to an increase for all radial tires to 89% from 72%.

Increased production of radial tires has had the effect of slightly decreasing use of rubber-processing chemicals. One reason for this

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Rubber handbook redux

Robert Ohm of R. T. Vanderbilt Co. has set the Oct. 9–12 meeting of the Rubber Division in Washington, D.C., as the target for continuing a tradition in the industry, "The Vanderbilt Rubber Handbook." Ohm is technical director of the Rubber Chemicals & Minerals Group and editor of the new edition.

Among changes readers will note are elimination of such fading products as hard and reclaimed rubbers. Hard rubber is cured with about 25 parts-per-hundred rubber sulfur and mixed with high loadings of anthracite coal for molding such parts as battery cases. Reclaimed rubber is salvaged from scrap tires and partially devulcanized by adding oils and treating with steam at about 400 °F. New to the 1990 edition will be tetrafluoroethylene-propylene-diene monomer and polyphosphazene rubbers, as well as membranes for pond and roof liners.

The most recent edition, published in 1978, contained almost 900 pages, and Ohm says the 1990 edition will be about the same. The dozens of contributed articles on individual elastomers, processing chemicals, fabricating technologies, and product types will be rewritten. Ohm has set most of the tables in vertical format so that users need not turn the book to read them.

Undecided for now is whether to add a separate index by trade names to the existing subject index; and whether to include an explanatory listing of the many abbreviations and acronyms current in the industry.

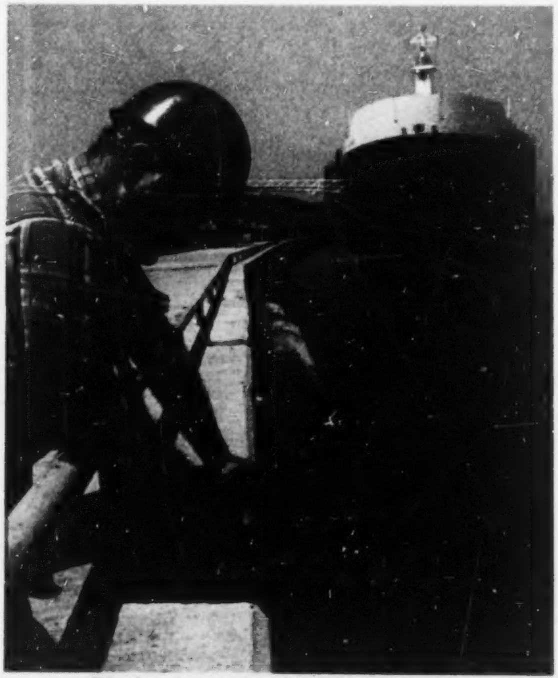
One part of the tradition cannot continue, though. Vanderbilt distributed previous editions of the handbook free as a service to the industry. Rising costs of publication will force the firm to set a per copy price of $100 on the 1990 edition.

change is that radial tires require larger amounts of natural versus synthetic rubber. Natural rubber contains proteins and lipids, which function as antioxidants, leading, in turn, to decreased amounts of synthetic organic antioxidants needed during fabrication.

A second reason is the longer lifetimes of radials compared with other types, resulting in longer times between replacements. But if natural rubber needs lesser amounts of antioxidants during processing, it requires greater amounts both of antioxidants and antiozonants to protect radial tires in service. This is because oxygen and ozone attack tire rubber even when the car stands in the garage.

Natural rubber does take larger amounts of peptizers than does synthetic. This is because natural rubber has a higher viscosity during fabrication, which those additives help reduce. But even with factoring in peptizers, continued penetration of radials will have an attenuating effect on rubber-processing chemicals use.

There is increasing consumer interest in high-performance, low-profile tires. These tires have a broader area of contact with the road, providing better traction. But these tires require more rubber to build than conventional tires, and the greater contact area gives them less mileage. To the extent that these tires penetrate the market, their greater rubber consumption and shorter times between replacements will expand the rubber-processing chemicals market.


Goodyear photo

Worker inspects rubber dock bumpers

Sizes of cars driven in the U.S. have decreased steadily since 1975, a situation which has meant a decrease in tire sizes also. But, recently, there has been an upturn in the use of larger automobiles, with a consequent demand for larger tires. The adoption of the 55-mph speed limit around 1975 contributed to greater tire mileage. If more and more states raise this limit, tire lifetimes consequently would be expected to go down.

Because markets for rubber-processing chemicals are mainly dependent on fluctuations in economies, the greatest opportunities for U.S. chemical companies may lie in Asia, Latin America, and the centrally planned economies of Europe and Asia, according to forecasts of IISRP. Though an organization of synthetic rubber producers, the institute includes natural rubber in its figures.

In Asia and Oceania (central and south Pacific islands including New Zealand and the continent of Australia), for example, rubber consumption may rise to 9 billion lb in 1994 from 7.9 billion lb in 1990 at an average growth of 2.7% per year. This growth is in contrast to the 1.4 to 1.5% rates expected for North America, Europe, Africa, and the Middle East. In Latin America, demand is expected to reach 1.86 billion lb in 1994, up from 1.64 billion lb in 1990, growing 2.6% annually.

IISRP analysts acknowledge difficulties in predicting the future in the centrally planned economies, which have undergone such profound changes in the past two years. Nevertheless, they put the growth rate at 3.1% per year to estimate rubber consumption of 11.3 billion lb in 1994, as compared with 9.9 billion lb in 1990. □

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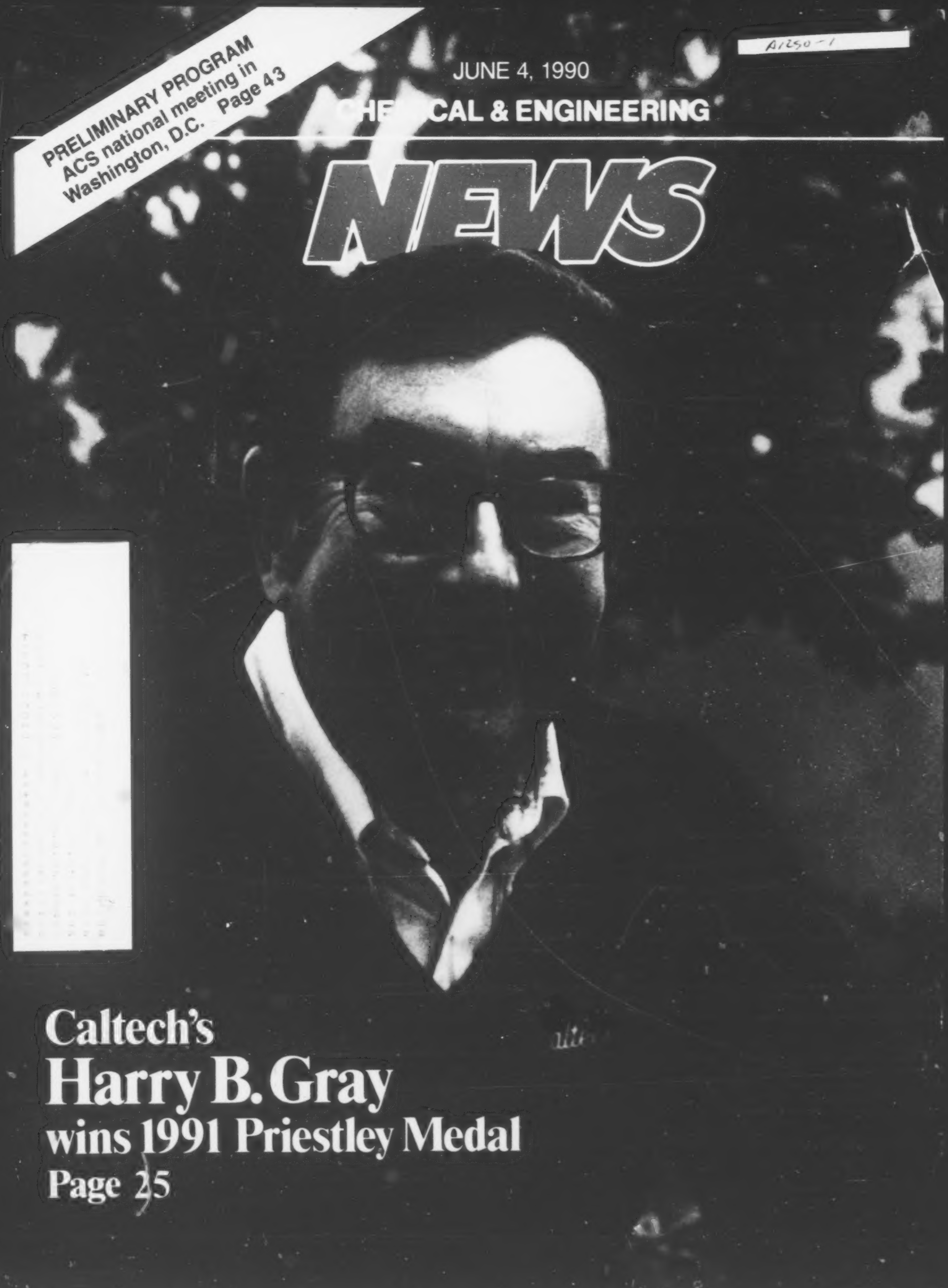
PRELIMINARY PROGRAM
ACS national meeting in
Washington, D.C. Page 43

JUNE 4, 1990

CHEMICAL & ENGINEERING NEWS



Caltech's Harry B. Gray wins 1991 Priestley Medal

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CHEMICAL & ENGINEERING
NEWS
JUNE 4, 1990

News of the Week

- **Production of chemical arms would be halted by pact to be signed last week by U.S., Soviet presidents at their Washington summit meeting.** Page 4
- **Chemist Bassam Shakhashiri, a popular proponent of science education, is being removed from his NSF post in a reorganization of the agency's education efforts.** Page 5
- **Indian government is pursuing court action to overturn Union Carbide's Bhopal settlement.** Page 5
- **UN panel warns of significant global warming in coming century unless emissions of greenhouse gases are curbed.** Page 6

Cover: Photo by C&EN's Rudy M. Baum

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Business

Arco Chemical's Harold Sorgenti discusses many issues and concerns currently confronting the chemical industry. **Page 9**

Government

Increased number of minorities in research is aim of NIH supplemental funding program. **Page 15**

R&D spending by the 50 states grew sharply in the eighties, according to an NSF-supported study. **Page 16**

Science Policy

Nikolai P. Laverov, chairman of the U.S.S.R. State Committee for Science & Technology, discusses Soviet R&D priorities. **Page 17**

Science/Technology

Search for a complete picture of hydrogen exchange reaction has led to close cooperation between experimentalists and theoreticians. **Page 32**

Books

"The Mind Has No Sex? Women in the Origins of Modern Science" is historical account of women striving to become scientists. **Page 41**

Preliminary Program

ACS's 200th national meeting this August in Washington, D.C., features variety of symposia; advance registration coupon provided. **Page 43**

Priestley Medal

Harry B. Gray, who is Arnold O. Beckman Professor of Chemistry at California Institute of Technology, will receive ACS's 1991 Priestley Medal, in recognition of his efforts in research and chemical education and his leadership in the chemistry community. Page 25

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LETTERS

CHEMICAL SAFETY: Silane distillation explosion

SIR: The letter from Jonathon D. Rich (C&EN, March 26, page 2) describing explosions that occurred during the distillation of 1,2-dichlorotetramethyldisilane prompted us to write concerning our experiences with the distillation of chloropentamethyldisilane.

On several occasions during the distillations (under N_2) of samples of chloropentamethyldisilane that had been prepared by the procedure of Kumada et al. [*J. Org. Chem.*, 21, 1264 (1956)], several violent exotherms occurred that resulted in rapid temperature increases to greater than 220 °C in the distillation head. In at least one case, these temperatures were realized even with the heating mantle removed from the apparatus. The pot residue after these exotherms consisted of a white solid that could be stored for extended periods of time at room temperature and which slowly released a corrosive gas (presumably HCl) in air. The reactions we observed were sufficiently violent that we have provided warnings in the experimental sections of two separate articles [*J. Organomet. Chem.*, 332, 271 (1987); and *J. Am. Chem. Soc.*, 111, 4809 (1989)].

We, too, highly recommend the use of adequate safety procedures and protective equipment when distilling chloropentamethyldisilane, 1,2-dichlorotetramethyldisilane, or related compounds.

Keith A. Horn
Research Associate
Allied-Signal Inc., Morristown, N.J.

Nonconjugated polymers

SIR: I read the report prepared by Stu Borman on "Alternate Theories of Conductivity in Nonconjugated Polymers Debated" (C&EN, May 7, page 53). Unfortunately, Borman did not cover the latest developments in understanding the mechanism of conductivity in nonconjugated polymers based on the recent experimental facts. We published a paper in the Dec. 15, 1989, issue of the *Journal of Chemical Physics*. (This work was also presented in the International Chemical Congress Meeting of Pacific Basin Societies, Honolulu, Dec. 17-22, 1989.) The results in this paper clearly resolve the issue presented in Borman's report. Our paper explains the molecular basis of conductivity in the nonconjugated polymers and shows that solid-state magic-angle nuclear magnetic resonance results clearly rule out the two models suggested by Bruce Hudson and Gary Wnek.

The cross polarization and magic-angle solid-state ^{13}C NMR data show that the concentration of double bonds is decreased upon doping. Double bonds are reformed as the doped sample is exposed to ammonia. This demonstrates the reversibility of doping.

Solid-state NMR data do not agree with the iodonium ion (π-complex) model proposed by Hudson. If Hudson's proposal were correct, then in the experimental solid-state NMR data the intensity of double bond should not decrease upon doping or increase after compensation with ammonia (reversibility of doping).

Iodinium ion (σ-complex) proposed by Wnek is also inconsistent with the observation of reformation of double bonds when the complex formation was reversed. According to Wnek, σ-complex is formed upon doping. If this were true then the doping phenomenon would be irreversible. The solid-state NMR results, however, clearly show that the double bonds are reformed once the doped sample is compensated with ammonia. The data presented in the Honolulu meeting also include the FTIR data to show the reversibility of the phenomenon.

Published solid-state NMR and FTIR data disagree with the proposals made by Hudson and Wnek and support the polaronic model.

A. L. Cholli
Lead Scientist, BOC Group
Murray Hill, N.J.

Reply: The paper by A. L. Cholli and M. K. Thakur [*J. Chem. Phys.*, **91**, 7912 (1989)] describes the results of ^{13}C NMR studies of iodine-treated polyisoprene. The major experimental observation reported is that iodine treatment results in a decrease in the intensity of resonances due to the two olefinic carbons in the 120- to 140-ppm region. New features appear in the aliphatic region of the spectrum (20 to 40 ppm) but there is no identification of resonances due to the hypothetical radical cation species proposed by these authors.

The loss of olefinic resonances is certainly understandable according to our proposal that complexes form between the carbon-carbon double bonds and the uate research assistant with supplemental funds from NIGMS. The young woman, Tracey Simmons, "may have the only room on campus with a periodic table for a wall poster," Fenselau says.

Without the salary provided by NIH, Simmons would have had to earn money at some other part-time job rather than spending time in the laboratory, according to Fenselau. "In my opinion she is progressing better through her science education because she has a connection with a working scientist, a 'lab home,'" Fenselau says.

Another minority undergraduate will spend the summer working in the University of Rochester laboratory of chemistry professor Douglas H. Turner with the support of the NIH program. "This is a good chance for him to do research," Turner says of the young man, who until now has worked as a dishwasher in Turner's lab. "He definitely would not have had the opportunity" without the NIH supplement.

Minority scientists with at least one year of postdoctoral experience, but who have never received their own NIH grants, can work with established researchers under another part of the program. They can receive a salary at a maximum rate of $40,000 per year either working full-time for short periods—the summer, for instance—or part-time over longer periods such as the academic year.

For example, a former postdoctoral student of Johns Hopkins University assistant professor Kenneth D. Karlin and who is now teaching at a small college will spend the summer working in Karlin's lab funded by an NIH supplement. Karlin says the fact that he already had a relationship with the minority investigator was considered a negative factor by NIGMS, but he was awarded the supplemental funds anyway.

High school students, graduate research assistants, and postdoctoral fellows are also eligible for support under the NIH initiative.

The announcement of the supplemental awards program was first published in the April 21, 1989, edition of the *NIH Guide for Grants & Contracts*. A revised announcement, which makes it clear that postdoctoral students are also eligible for support and clears up some other details, will be published in the same newsletter this summer.

Pamela Zurer

States' spending on R&D up markedly

In 1988 the 50 states devoted, on average, less than one quarter of 1% of their total expenditures to R&D-related activities and accounted for less than 1% of total R&D spending in the U.S. Taken together, they spent just over $1 billion for conduct of R&D and some $200 million in support of the R&D infrastructure.

Those are the findings of a survey conducted in late 1988 by Syracuse Research Corp., under a grant from the National Science Foundation, of R&D expenditures by state agencies. The results of the survey were recently published by NSF, which in 1977 sponsored the last survey of state R&D expenditures.

Five states rank in top 10 in both R&D spending . . .

$ Millions	
New York	$329.9
Maryland	175.8
California	76.3
Illinois	58.5
Pennsylvania	41.1
New Mexico	34.1
Ohio	33.4
New Jersey	22.8
South Carolina	22.0
Texas	21.1
TOTAL	$815.0

. . . and percent of total state spending devoted to R&D

Percent	
Maryland	1.88%
New Mexico	1.13
New York	0.86
Nevada	0.61
Wisconsin	0.52
Alaska	0.42
South Carolina	0.37
Illinois	0.34
Idaho	0.33
Montana	0.24

Note: Fiscal year 1988.
Source: National Science Foundation

Comparing the two surveys shows that states' R&D expenditures, excluding R&D plant, grew a healthy 193% between 1977 and 1988. Factoring in inflation drops that number to 62%. Federal R&D expenditures increased by even less, 55%, during the same period.

In 1977, 10 states accounted for 64% of R&D spending by the states, with the top five contributing 50%. By 1988 R&D expenditures were more concentrated: The top 10 accounted for 78% of all R&D spending, with the top three alone contributing over 55% of the total.

New York spent the most on R&D—nearly $330 million—and accounted for 31% of R&D spending by the states in 1988. New Hampshire spent the least—nothing. Maryland was second at about $176 million. California ranked third at $76.3 million, according to the survey, but that may be a low estimate.

The survey specifically excluded direct appropriations to universities and colleges from its R&D database. Since California's constitution mandates that its state university and college systems act as the state's major research arm, the report says, California's total R&D commitment, and possibly that of other states, may not be adequately reflected in its ranking.

The five most popular research areas reported by the states in 1988 were health at $286 million; energy, $108 million; natural resources, $106 million; science- and technology-based, $105 million; and economic growth and productivity, $64.2 million. The report notes that research spending in the latter two categories increased from a combined total share of 2% in 1977 to 19% in 1988.

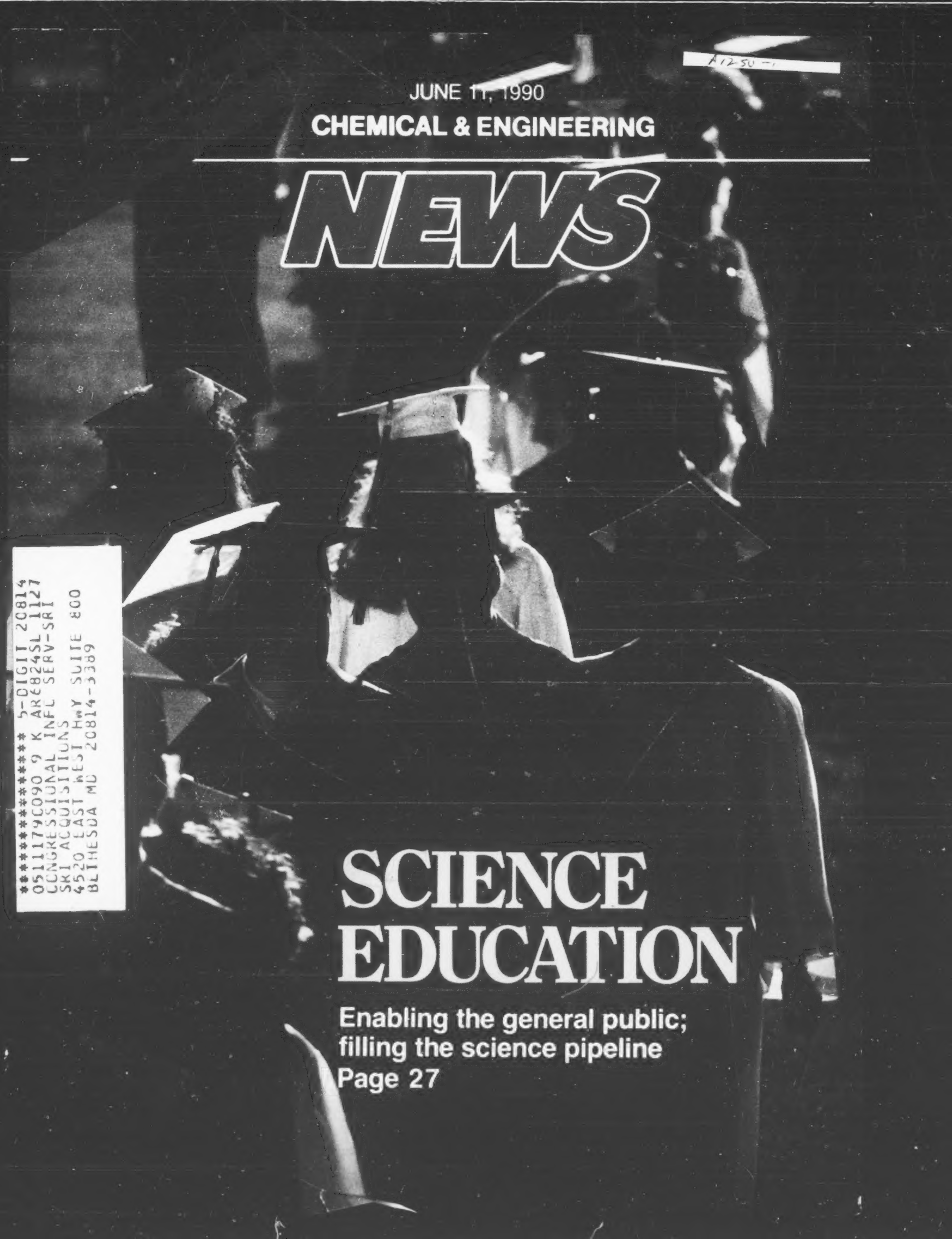
Single copies of "Research and Development Expenditures of State Government Agencies: Fiscal Years 1987 and 1988," Special Report, NSF 90-309, can be obtained free from the Division of Science Resources, National Science Foundation, Washington, D.C. 20050.

Janice Long

A1250-1

JUNE 11, 1990

CHEMICAL & ENGINEERING NEWS



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SCIENCE EDUCATION

Enabling the general public; filling the science pipeline
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CHEMICAL & ENGINEERING
NEWS
JUNE 11, 1990

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- **NAS report endorsing alternative agricultural techniques wins some support from agricultural establishment at Congressional hearing.** Page 4
- **Federal agencies face costs of more than $150 billion for hazardous waste cleanups at federal facilities.** Page 5
- **UNESCO to organize international chemistry curriculum modeled after ACS's ChemCom curriculum.** Page 5
- **Scientists and economists in Gorbachev's entourage meet with U.S. counterparts during summit in Washington, D.C.** Page 5
- **Stock market hit new high early last week, but chemical stocks are not joining in the action.** Page 6
- **Groundbreaking ceremonies for Advanced Photon Source took place last week at Argonne National Laboratory.** Page 6

Cover: Photo by John Kleinman/
Uniphoto Picture Agency

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Business

Du Pont is stepping up its efforts in Europe with the goal of doubling sales there over the next decade. **Page 9**

Government

Congress has been absorbed with environmental issues, particularly overhaul of the Clean Air Act, in the past month and a half. **Page 14**

Parsons Award

Mary L. Good has been selected to receive the American Chemical Society's 1991 Charles Lathrop Parsons Award. **Page 16**

Science/Technology

Chemists are crucial to progress in design of nonlinear optical materials that use light instead of electricity for computer, other applications. **Page 21**

Selenium-containing nuclear magnetic resonance shift reagent determines optical purities of chiral compounds. **Page 25**

Reagents that selectively cleave proteins are developed by two independent research groups. **Page 25**

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Special Report

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LETTERS

Animals in research

SIR: The article "Animals in Research" (C&EN, May 7, page 9) did what anyone exploiting the helplessness of other living beings must do: resort to distortions in order to avoid facing truths that are inevitably discomforting and occasionally life-changing.

You asked, "Do animals have rights?" Your insightful answer: "Every active biomedical researcher interviewed for this article says 'no.'" But perhaps you might have asked Donald Barnes, a former career vivisector who now heads the National Anti-Vivisection Society. Or Michael A. Fox, who wrote a book called "The Case for Animal Experimentation," and upon further reflection had the courage to denounce his book and become a vocal animal rights advocate. They and thousands of others have concluded that humans aren't the only species deserving to live without purposely inflicted suffering; that "First, do no harm" should apply to all beings capable of feeling pleasure and pain.

Finally, the article insinuated that animal rights activists have "invented" utilitarian arguments against animal experiments because people wouldn't otherwise be persuaded. In fact, we have no need to invent arguments, as millions of humans have already become victims of a health care system that ignores the poor and emphasizes the search for dubious "cures" despite the fact that heart disease, stroke, adult-onset diabetes, and 30 to 60% of cancer causes are preventable. According to the *New York Times*, Louis Sullivan, Secretary of Health & Human Services and animal rights opponent, has stated, "More healthful living, which includes quitting smoking, using seat belts, reducing violence, and eating more nutritiously, is the key to improving health. That is clear in light of findings that more than half the causes of premature death are related to patterns of life."

Jill Leonard
People for the Ethical Treatment of Animals

SIR: The article on the animal rights issue was an excellent article in informing scientists of the increasing problems presented by the so-called animal rights activists. As a research chemist for a major agricultural chemical company that must use animal testing in registering or reregistering products, we are very much concerned with the explosive growth of these militant groups and the problems they present with the advancement of scientific knowledge.

As an avid hunter I have had many encounters with these animal rights activists and I feel that my experiences and observations will be of benefit to those scientists who are just getting their feet wet in dealing with these people. These people are fanatically dedicated to their crusade; no amount of hand-wringing or wishful thinking will make them go away. No amount of logical thinking supported with scientific facts will divert them from their moralistic and emotional arguments. Any person who thinks that he can make a compromise with these people is a fool. Today's compromise is the basis for tomorrow's negotiations on additional compromises. To the animal rights activists, the concept of animal rights is an all or nothing proposition. There is no middle ground. The animal rights groups are very well financed and actively recruit celebrities as their qualified spokespersons.

The general public is uncommitted to the animal rights movement. They will listen to logical presentations supported with scientific facts. We scientists must do a better job of educating the public to the benefits of the use of animals in research. In doing so, they will see the animal rights activists for the narrow-minded zealots that they are.

The next time you read about or hear a news item that projects hunters in a negative image, please remember that the sources are the same as those who are running smear campaigns to end the use of animal research. Hunters, trappers, and scientists may make for strange bedfellows, but we all are in the same boat when dealing with these narrow-minded people. Perhaps an effort by all of us to support one another will greatly aid in educating the public of the narrow-minded militant stance posed by these activists.

John Vargo
Greensboro, N.C.

SIR: The evident hostility toward animal rights advocates displayed in the recent article on the use of animals in research was disappointing but not surprising. The American Medical Association launched last year a campaign to dis-

Continued on page 50

Corrections

- May 21, page 21: The 50-year history of the Chemical Marketing Research Association was prepared by William E. Marklewitz, a former CMRA president, not by Henry F. Whalen Jr.
- April 23, page 3: The sentence in the second paragraph of the letter on the toxicity of chlorofluorocarbons should read, "More recently, a CFC . . . was shown to act as a cocarcinogen," not carcinogen.

Winds of Revolution Sweep Through Science Education

Science education, including chemistry, is on the verge of major restructurings as responses grow to personnel pipeline crisis and public literacy issues

James Krieger, C&EN Washington

When social historians of the future look back on 1990, they may mark it as a pivotal year in the reform of science education in the U.S. True, expressions of concern have been filling the air for at least the past five years. And a number of programs taking action to address science education needs have come into being in the past year or two. But those concerns and programs are now building into something of a movement for reform that, if it continues to broaden and deepen, could completely change the face of science education in the U.S. from cradle to college.

Among the factors intensifying the situation are two major issues that have come together and reinforced each other: on the one hand, science education and science literacy for the general public, and on the other, filling the science personnel pipeline in the relatively near future. Exacerbating these issues are the spreading concerns about shoddy education in general and its impact on U.S. competitiveness.

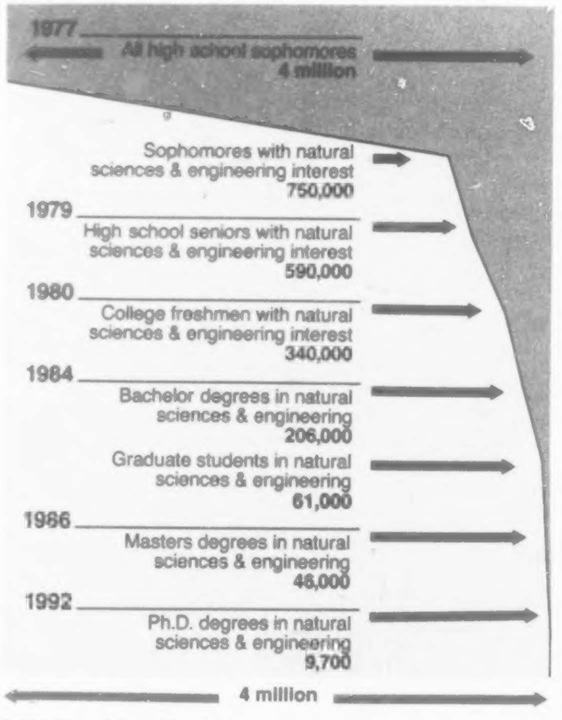
The public education and pipeline issues run parallel, sometimes merging to become one, sometimes exhibiting separate aspects. Now common to both is an overarching realization that solutions must be comprehensive. Piecemeal approaches help but aren't sufficiently encompassing.

Chemistry is certainly caught up in this maelstrom of concern that is sweeping through science. Indeed, both the public education and pipeline themes permeated the program in Boston at the recent national meeting of the American Chemical Society.

"Wouldn't it be great," said one speaker in Boston, "if this ACS meeting could fire the shot heard round the world for the education of America's young people."

The Boston ACS meeting is not likely to gain that distinction. A strong case can be made that it already belongs to the 1983 "Nation-at-Risk" report by a Department of Education panel that stated "the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and a people." Indeed, a recent editorial in the *Washington Post* noted that reports lamenting the perilous state of this country's scientific literacy now number above 300.

The science pipeline: Constricting to a trickle of Ph.D.s



Source: National Science Foundation

Nevertheless, the ACS meeting can lay claim to an effort of consciousness-raising in the chemical community on an unprecedented scale and perhaps to a sharp escalation in the energy level of that community in pressing for change. The energy will have to be sustained. No one believes there is any sort of short-term solution available for something that has, by all accounts, gone terribly awry.

Variety of groups working for educational change

The activity generated over recent years has been taking place across a broad front. In just the past 16 months, notable efforts have come from scientific societies, from industry, and from government. Among them:

- In February 1989, the American Association for the Advancement of Science released a report "Science for All Americans" as the first phase of its Project 2061 (C&EN, March 13, 1989, page 22). Project 2061 (named for the next appearance of Comet Halley, which will be seen by children in school today) is a long-term effort for achieving science literacy aimed at precollege education. "Science for All Americans" focused on defining the substance of science literacy. Phase II, now under way, is focused on development of new curriculum models and reform of teacher education, teaching materials and technologies, and other areas.
- In April 1989, Sigma Xi, the scientific research society, reported on a conference of a National Advisory Group it had convened in January. The charges to the advisory group were to explore the nature and quality of undergraduate education in science, mathematics, and engineering, and to identify the significant topics and issues that should be addressed in charting policy for undergraduate education in science, mathematics, and engineering.
- Last year, a Union Carbide corporate task force on education spent six months studying public education in the U.S. to determine the implications for Union Carbide and to recommend a role for the corporation in addressing national education issues. The task force's report, "Undereducated, Uncompetitive U.S.A.," recommended Carbide support and initiate programs designed to bring down barriers to school reform and to stimulate change, with efforts directed both externally to the general public and internally to the company's employees.
- Last November, ACS held a briefing for Congress on a newly formulated white paper called "Education Policies for National Survival" (C&EN, Nov. 27, 1989, page 54). The white paper was a synthesis of more detailed policies developed by ACS that were concentrated into one succinct form by a subcommittee of the Society Committee on Education. It offered some 70 recommendations for actions that would address all levels from kindergarten through university and graduate training and continuing education of teachers and scientists.
- Early last month, AAAS dropped the other shoe with its report, "The Liberal Art of Science" (C&EN, May 14, page 4). A college-level counterpart to "Science for All Americans," the new report urges colleges and universities to restructure their degree programs so that all graduates acquire a broad understanding of science and its impacts. Science majors and nonmajors alike, the report says, should be taught science as a liberal art.
- Also early last month, the National Science Foundation added to its existing science education efforts, soliciting proposals under a program for statewide systemic initiatives in science, mathematics, and engineering education (C&EN, May 14, page 4). The program seeks to enlist the political leadership of the state, the business leadership, the civic leadership, universities and colleges, and the public school systems to bring about systemic change statewide.
- And late last month, the Department of Energy weighed in with release of a report detailing the results of a Math/Science Education Action Conference it had convened last October at Lawrence Hall of Science in Berkeley, Calif. (C&EN, May 28, page 8). Accompanying the report was a delineation of science education initiatives at DOE laboratories, along with memoranda of understanding with various organizations such as the National Aeronautics & Space Administration and the Appalachian Regional Commission, all focused on science, engineering, and mathematics education.

Judging from current anxiety over where the future supply of scientists will be coming from—how the pipeline will be filled—such actions come none too soon. In fact, they may already be too late to alleviate shortages in the near term.

"As we look down the road for the next 10 years, we see that the retirement curve is going to go up very dramatically," says Paul G. Gassman, University of Minnesota chemistry professor and president of ACS. "At the same time, the production curve is going to go down very dramatically. These are going to cross rather drastically. I think the collision is going to spell disaster."

Gassman, along with Betty M. Vetter, executive director of the Commission on Professionals in Science and Technology (formerly the Scientific Manpower Commission), and Bassam Z. Shakhashiri, then assistant director for science and engineering education at NSF, wrestled with the pipeline issue at the presidential plenary session at the Boston ACS meeting. Gassman chose the issue as the subject of the session, he says, because of "my very great concern that as we approach the 21st century we will not have sufficient scientists to maintain our status as a strong industrial nation, and this will very dramatically impact on our overall economy, and certainly on our ability to train future scientists."

For chemistry, the crunch will not be long in coming. Colleges and universities today, Gassman points out, are generating about 200 new positions per year for chemistry faculty because of retirements. Since the schools are about one year behind in filling the openings, there are about 400 at any given time. In five years, Gassman says, there will be 300 openings generated per year. In 10 years, there will be 500. In 12 years, openings will increase to very close to 600 per year. That is just the academic demand for Ph.D. chemists.

The contents of the pipeline that will be supplying the chemists to meet that demand as well as an antici-

Photos by C&EN's James Krieger

Shakhashiri (left to right), Gassman, and Vetter express concern over the ebb in number of students preparing to enter the personnel pipeline

pated increase in demand from industry are very well known. "We can tell you plus-or-minus 50 how many Ph.D. chemists will graduate every year to the year 2000," Gassman says, "and we know that we will not begin to meet the numbers that we will need."

Overall figures give the impression that production of Ph.D. chemists has been fairly constant. But, Gassman points out, there are some very misleading data hidden there. For example, the number of foreign nationals in the group receiving chemistry Ph.D. degrees has increased sharply and continues to rise. During the same period, the number of U.S.-born students receiving chemistry Ph.D.s has decreased and recently has dropped off very rapidly.

Everyone who is going to get a Ph.D. degree in chemistry in the 1990s is either in undergraduate school or graduate school right now, Gassman notes. Thus, in the mid-1990s, 125[illegible] U.S.-born Ph.D. chemists will graduate per year.

And fewer and fewer have any interest in academic jobs. In 1970, the National Research Council surveyed all graduating Ph.D.s in chemistry and found that 18.5%—411 individuals at that time—wanted academic jobs. The same survey 15 years later (it is conducted at five-year intervals) found only 8% of graduating Ph.D.s in chemistry wanted academic jobs. That percentage equates with just 147 individuals.

One reason for the drop, Gassman says, is that there is a perception among students that the life of a professor is no longer so attractive as it was at one time. For instance, students see their advisers struggling for grant funds. "Today one writes roughly three times as many proposals to get a grant, on average, as one did 10 years ago," Gassman explains. "This has a very dramatic impact on the attitudes of students and on their tendencies to want to go on and teach the next generation."

Gassman points out that until now, there has been in the U.S. a pretty good balance between supply and demand of scientists, and it has been possible for universities to fill academic positions with reasonably qualified people. Part of the problem Gassman foresees is that "when supply and demand get totally out of kilter, we will have hired into our universities, when they can be found, people who are less qualified. They will train the next generation. This is just a long-term effect, which takes several generations to cure."

Hence, the situation is not one for which there is any kind of quick fix. The pipeline for chemistry, Gassman points out, is now an 11-year pipeline, from the start of undergraduate school to the receipt of a Ph.D. Even if it were possible to change the attitudes of incoming freshmen, it would be 11 years before the impact would be felt. But Gassman doesn't believe there are individuals coming out of high school who are adequately trained in math and science, and adequately motivated toward science to be able to have a major impact on supply 11 years down the road.

"From my own perspective," Gassman says, "I think it will take a minor miracle to graduate as many U.S.-born Ph.D. chemists in the year 2010 as we did in 1985."

As for drawing on foreign scientists as a way around the problem, that may not be so easy in the future as it might appear. The foreign competition is getting much better, Gassman says, citing Taiwan as an example. One of the major sources of graduate students in chemistry in the U.S., he explains, has been Taiwan, but today the number of applicants from Taiwan is dropping off dramatically. The reason, he says, is that "Taiwan has built very fine universities, it has hired faculty from throughout the world to staff those universities, and they are keeping their students at home."

Nor may there be much solace in recalling how 30 years or so ago, the U.S. rallied in response to the orbiting Sputnik satellite to increase the flow of talent into careers in science, mathematics, and engineering. NSF had a lot to do with that increase. Says Shakhashiri, "I think the situation we face now is by far more critical and more consequential than what we faced back then."

It is so for several reasons, Shakhashiri says. One is the tremendous change in scale of the problem that has occurred in the past 30 years as the population of the U.S. has increased by 50 million people. That change, he says, means there are more students to teach and there is a greater need for qualified teachers at all educational levels, not only precollege and undergraduate levels but also the graduate level. Moreover, there is the pipeline problem with a decreased flow of talent going into areas of teaching science, mathematics, and engineering. And third, the scientific and technological nature of society is much more advanced, requiring attention be paid to the nonspecialist.

Fewer students intensify the problem

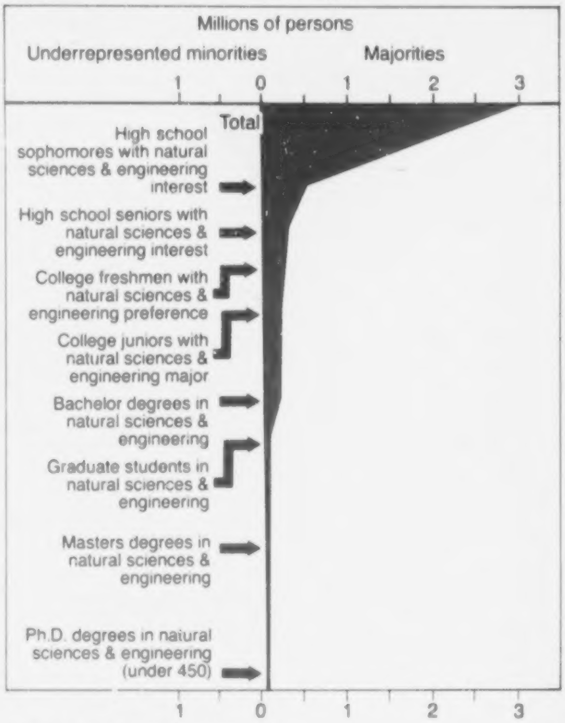
Overall demographics also provide little reassurance. There are fewer college-age students today than there were in the mid- to late 1970s, explains Vetter, and the size of that population will continue downward through the mid-1990s. Not only is there a 25% drop in the size of the college freshman population, she adds, but the racial and ethnic characteristics of those potential freshmen also are changing significantly. Today's elementary children include more black, Hispanic, Native American, and Asian than is true for the American population as a whole, so students of college age must increasingly be drawn from minority groups.

In addition to the drop in college-age students, the white male population from which scientists traditionally have been self-selected is a shrinking portion of the college-age population, Vetter points out. Within the overall contracting population, students have been indicating less interest each year since 1982 in majoring in any of the natural science or engineering fields.

Moreover, Vetter says, each year since 1982, fewer and fewer merit scholars have chosen these fields. The percentage of merit scholars choosing science has dropped from 23% to 19% just since 1982, and the percentage choosing engineering has dropped from 26% to 20% in less than five years. "So," Vetter says, "we have a quality problem as well as a quantity problem."

That's at the undergraduate level. Like Gassman, Vetter also notes the increasing number of foreign citizens at the graduate level. There were 1971 Ph.D.s in chemistry awarded in 1989, she points out, and of these 28% were awarded to foreign students. Of the American students, the percentage of men earning the degrees was down 11% in one year. The number of women earning them was up 11%—though from a small base—for a net combined 6% drop. Only 8% of the Americans gaining Ph.D.s in 1989, Vetter says, were black, Hispanic, Native American, or Asian. This was the same percentage as in 1988, although these groups make up about 30% of the U.S. population.

The science pipeline: Underrepresented minorities are one untapped source...



Source: National Science Foundation

"If we need to increase the numbers," Vetter says, "and there appears to most of us to be little doubt that we do, then our very best source will be women and, to a somewhat lesser extent because there are fewer, minority males." But, Vetter adds, there are many barriers, both apparent and hidden, to increasing the interest and participation of these underutilized groups.

Salaries paid to women, for example, are lower than those paid to men, even at the first position after the doctorate, Vetter says. Since women progress more slowly in terms of salary increases and are less likely to be moved into management positions, the differential increases with years of experience. The salary gap between men and women for a typical doctoral scientist averages about $9000 per year. "Over a lifetime," says Vetter, "it is easy to see why women should be discouraged by this. They are, after all, charged the same fees and tuition as their male classmates."

If there is to be an increase in production of scientists and engineers to meet expected needs for the coming decade and the start of the next century, Vetter says, steps must be taken now to supplement the potential supply. There are just two choices, she maintains: Assume there will be enough if nothing is done; or assume that there will not be enough unless something is done.

"Personally, I'd prefer to plan for the latter scenario," Vetter says. "If this turns out to be wrong, there are many productive ways to utilize doctoral scientists. But if we make the first choice, there are no later options in case we turn out to be wrong."

Narrowing the focus to a single school adds a more personal touch to the disciplinewide situation. It doesn't, however, make it any more hopeful, at least in experiences such as those at Purdue University. Kay A. Conner, undergraduate adviser to chemistry majors and to science majors in general at Purdue, has made an analysis of the freshman class of 1987. There were 97 entering freshman chemistry majors. In the fall of 1989, only 15 of the 97 were left as chemistry majors. "I was amazed," says Conner, who then decided to find out where they had gone.

Of the remaining 82, 20 had dropped out of school, and 62 had chosen another major. An informal poll, Conner says, indicated that the management school would have been the first choice for most of them, followed by the engineering school. But those schools were difficult to get into, taking students according to space available.

So, a large number of them, 16, went into liberal arts. Nine went into biology, eight into health sciences, and three each into management, agriculture, consumer and family science, other science majors, and technology. Conner summarizes these data by saying almost all of the 62 chose an easier major—meaning they could get by with taking less math, less physics, less chemistry, and not having to work as hard. The 15 chemistry majors, Conner says, were the better students.

Chemistry did recruit some students from other areas, bringing the class to 37 students. Six came from chemical engineering, five from biology, three from other engineering, two from physics, one from math, and five were transfer students who generally were majoring in chemistry at the other school.

And 1987 was not an unusual year, Conner says. From 1985 to 1988, 379 started in chemistry; 74 stayed in chemistry.

This past school year for the first time, Conner says, she put together a profile with a wide variety of information about incoming freshmen. The most important thing she found, she says, was information regarding the first-year math course: Of 95 chemistry majors, 40% were starting out in remedial math.

The first-year math requirement is based on an entry-level algebra/trigonometry test—a "simple" test, Conner says, "and 40% of our incoming school of science students that would like to major in chemistry cannot pass this test." This is despite the fact, she says, that 100% of them had had at least three semesters of algebra with high grades, and most of them had also had at least a semester of trigonometry.

Student anecdotes paint a not-too-pleasant picture

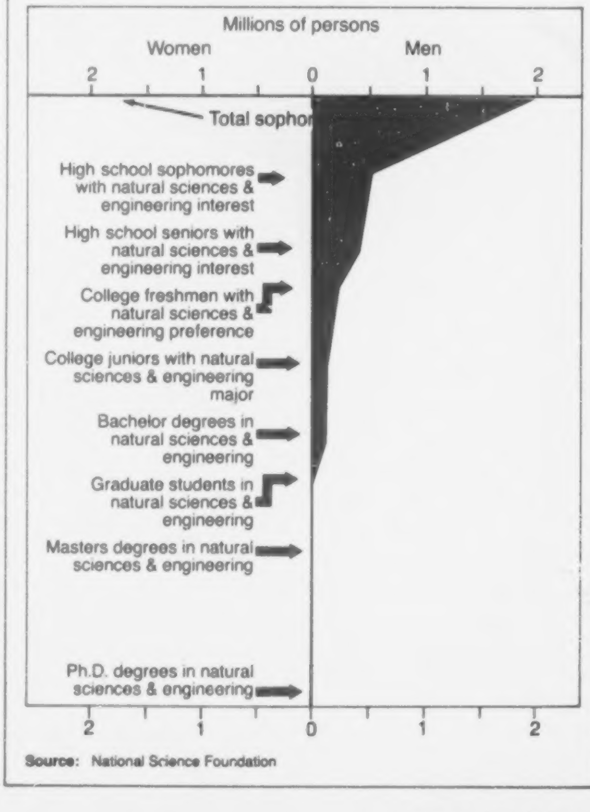
Conner notes the most common reason students are saying they would like to switch to another major is that chemistry is too hard. They're not prepared for it. They're not able to handle the math and the physics. "A lot of them didn't know they were going to have to take physics," Conner explains. "They had a good time in high school; they had a high-school chemistry teacher they liked; they had fun in high-school chemistry lab; but they didn't have to know any math and they didn't have to know any physics."

Another big problem, as Conner sees it, is a common attitude of students that is strongly supported by parents. The attitude is that they are in college not to get an education but to prepare for a career. They want that career to pay as much as possible, but they'll settle for less money if they don't have to work as hard.

Not just difficulty with math and science but experiences with science that can only be described as appalling have been responsible for turning students away from majors in the natural sciences. A vivid impression of these experiences emerges from condensations of student "science autobiographies" collected by Nancy Brickhouse, a professor at the University of Delaware in the department of educational development.

"I found thoughts of science and dissecting animals and microscopes and complex formulas intimidating," writes one student. "In high school, I began to dislike science, and I found it to be very frustrating. In elementary school, I liked science. However, in high school, my opinions about science . . . began to change. I found the material—particularly what we were learning in chemistry—to be very difficult and frustrating. I also had a couple of teachers who completely turned me off to science. They may have known the material, but they just were not very good at teaching it. I can remember sitting at my dining room table with my Mom trying to do chemistry problems. I remember just cry-

The science pipeline:
. . . and women represent another



Source: National Science Foundation

ing because I had no idea how to do them, and my teacher felt as though we should be able to do them even though she hadn't taught us. It was a horrible year in chemistry for me."

Another student writes: "I did not choose a science-related career because I never did well in science. As a younger child I remember doing science experiments in class. And I did like them a lot, but I guess it was in high school that I started to dislike science. I never failed or got a D, but it was something that got me flustered and confused. In high school, I took biology, chemistry, geology, and physics. I liked biology; my teacher knew I had a little difficulty with science and he helped me a lot. On the other hand, I really disliked chemistry. I could study four hours straight and still find some way to make a mistake. My teacher was another reason I did not like this class. He was very boring, and he never clearly explained things. In college, it all changed. When I took biology, I hated it. There were so many different concepts and ideas that all I could do was to be confused."

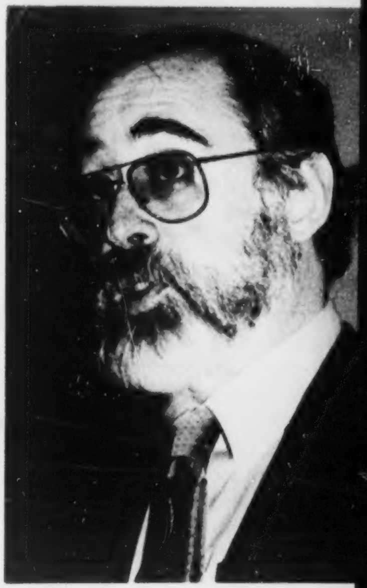
Plaintively, a third student writes: "My experiences with science have been like a roller coaster. Everything started out well enough. I went to high school with a very optimistic outlook about science. I first encountered [my teacher] for biology who awarded me my first D, and to top it off he told me I deserved it because I was immature. Such a lovely man. Next ego basher was [my chemistry teacher]. She was retiring after that year. We all felt cheated. Why couldn't she have just retired the year before? During the first week of school she said that she didn't need us, but we needed her to pass. She said she would fail people and didn't think twice. She actually found joy in it. So I became her prophecy and received my first and only failing grade. Such a lovely woman. Onward to [my physics teacher]. College science courses weren't nearly as harsh since they brought an upswing on the roller coaster. I did not choose a science-related career because science has been rather traumatic through most of my older years, and why dedicate my life to squeezing the wound?"

There are many more examples. Commenting on them, George M. Bodner, professor of chemical education at Purdue University, notes that the vast majority of the students had taken biology, chemistry, and frequently physics at the high school level—all the courses that they would have needed at that level to become science majors. But they didn't. On the basis of these observations, Bodner has developed nine assertions, or generalizations.

First, some students are driven away from science in the elementary grades because it is obviously less important than the really important subjects like reading, mathematics, language arts, or the social sciences.

"If it were important," Bodner says, "we would be doing it. We wouldn't do it at the end of the day. We wouldn't be doing it when we run out of useful things to do." If you don't have teachers at the elementary level who value doing science, he adds, if you don't have people at the elementary level who know how to do science, you're going to lose some of your potential majors at that point.

KAY A CONNER



Bodner next asserts students are driven away from science in middle school when it is taught as a product rather than being presented as a process.

If science is nothing but a regurgitation of facts, Bodner says, it is boring. "If it is a science, a process, where you do observation, where you do analysis, where you have to think, where you have to predict, then the students enjoy it—sometimes even the teacher enjoys it—and some of them go on."

His third assertion is that students are driven away from science when the discipline is taught as knowledge without understanding.

As a fourth point, Bodner says students are driven away from science when the only alternative seems to be memorization of facts (which are boring) and equations (which are meaningless).

Fifth, Bodner says students are driven away from science when they are confused or frustrated. It's possible to keep very high standards in a course, Bodner maintains. "Indeed," he says, "that may be what one of our functions in life is. But that doesn't necessarily mean that students need to walk away from the course with the feeling that they can never understand, that they can never manage, that they can never be successful in science, that it takes a special kind of individual to be a scientist.

Bodner's sixth assertion is that students are driven away from science by strict adherence to rules; when creativity is actively discouraged.

Bodner tells a story. "I have a colleague," he relates, "who had a young son who took a course. He came home from a middle school science course in tears because the teacher had failed him on an assignment. And he failed him on the assignment because the assignment was a graph. And what the student plotted

Crosby (clockwise from above), Bodner, Conner, and Lagowski decried state of science curricula during recent ACS national meeting

on the y axis has to go on the x axis, and if you don't reverse the axes, it's obviously wrong. So if you don't produce the axes like it was in the textbook, you get zero credit."

Bodner's seventh point is that students are driven away from science when it has no relevance to their lives.

His eighth assertion is that students are driven away from science by teachers who cannot explain what they know.

Right now, Bodner says, chemistry and physics majors are being graduated to be teachers who don't do well in the classroom. They want to do a good job, he says, but they are not being armed with the skills needed to do a good job. They are getting most of the content knowledge that they could hold at the time they graduate. But they are being provided with virtually nothing in the way of pedagogical content knowledge, he says.

For his final assertion, Bodner looks to Latin to explain: De gustibus non est desputandum. Basically, Bodner quips, this means that in spite of everything, there is no disputing taste. "Some people will still, in spite of everything we do, decide to become scientists. If we could find some way of gently increasing that, then the field would probably be a little bit healthier."

Gentle is not the approach some would use toward introductory chemistry. Indeed, the early college experience is one that has many chemical educators issuing impassioned calls for reform and revitalization in words that sound like revolution.

"I think we need to revitalize the undergraduate program. And I don't think we can tinker with it," says Glenn A. Crosby, a chemistry professor at Washington State University, Pullman. "I think we should dynamite it and start over."

For many reformers, the undergraduate program is the focus of numerous issues. There is the issue of appropriate attitudes toward majors and nonmajors, issues relating to curriculum and to laboratory facilities, the issue of the proper role for teaching versus research.

"We've got to start looking at the nonmajors," Crosby states. "God must have loved the nonmajors," he says, "he made so many of them." Yet, he adds, chemical educators have forgotten the nonmajors. "We're going to have to turn our attention to the education of the entire populace and not just [those] that might get replicated in our own image."

Crosby sees a danger in emphasizing chemistry in particular and science in general as a vocation rather than as an education. Noting that in his opinion, chemistry is a new liberal art, Crosby says, "We've been indicating that if you study chemistry, you might get a good job. And that may be true. But I think that's ancillary to the fact that we should be teaching chemistry for what it is: something that without the knowledge of it, one cannot live in psychological comfort in the last half of the 20th century and certainly not in the 21st."

Joseph J. Lagowski, a chemistry professor at the University of Texas, Austin, also believes a disservice has been paid nonchemistry majors, though they may have indicated an interest in science, and that the whole ambiance is bad for attracting chemistry majors. This, he says, has drastically affected retention rates for aspiring chemistry majors. He describes the ambiance as one where students find that if they are going to be seriously considered as junior colleagues in the discipline, they have to come already committed to the discipline.

In many large institutions, Lagowski says, chemistry majors are essentially sequestered and expected to take an honors course or the equivalent. The rest of the science majors go into a different course. The chemistry course for science majors generally doesn't get the resources that the other courses get. Classes are generally large. The resources with regard to the laboratory component are generally poor. And very often the faculty members are "less than enchanted" in trying to teach these students.

Says Lagowski, "We're essentially saying to a very large number of people who fundamentally have an initial perceived interest in the physical sciences, 'No, no, we're not going to take you seriously unless you come to us already annointed as a chemistry major.' "

If one looks at many of the things done in chemistry, Lagowski says, "we do it as a service to other disciplines. And we don't do it well. And then we are unhappy because our discipline is going down the tubes."

"Why do we study chemistry?" asks Oregon State University chemistry professor Stephen J. Hawkes. It would be nice, he says, to believe that students are being made to study chemistry so that they can make good decisions. "But, you know," he says, "to come right down to it, I haven't been able to think of many decisions that a person with one year of chemistry would be able to make."

There is the matter of communications. "I have students," says Corvallis-based Hawkes, "who have told me as they dropped my course, 'If ever I need any chemistry done, I'll hire a chemist.' And my reply is, 'No you won't. Because you don't know enough chemistry to know that you need a chemist.' I think we need to teach them enough chemistry so that they know that there are problems that the chemist can solve."

And they are not common problems about the pH of 0.1M formic acid, Hawkes adds. Hawkes, like many chemical educators, is concerned about the irrelevancy of the introductory chemistry curriculum to many students. Having given the matter some thought, he says, he has come to a conclusion: Chemistry is boring. "I have been getting around to wondering," he adds, "why anybody ought to find it interesting."

Hawkes describes an experience he had recently when, in preparing for a chemical meeting, he asked some chemists if there were comments they would like to make about general chemistry. One of them reacted explosively, Hawkes relates. "He said, 'Yes! I have two kids in high school who are taking high-school chemistry, and what they are teaching them has nothing to do with what I do for a living.'"

What do chemists do? Hawkes asks. Chemists, he says, design things, like cracking processes for petroleum; they formulate things, like water repellents; they analyze things, like their competitors' products; they synthesize things, like lightweight plastics; they isolate things, like bromine from seawater; they predict things, like how long it takes for gasoline to be carried away once it gets into the atmosphere; they prevent things, like corrosion.

"I have a feeling," Hawkes says, "that the reason that everybody says you've got to have a lab in freshmen chemistry is that the chemistry that we teach them is so irrelevant to anything in their experience that you've got to have them in the lab so they see something concrete. If we could only talk about the chemistry of real life, they wouldn't need to see it in the laboratory; they could see it walking down the street."

It's all very well to say what you put into general chemistry, Hawkes notes. Perhaps more to the point is what should be left out. The first question that should be asked about anything that students have to learn is why they should know that. "I think if we were to ask that question a lot more often," Hawkes says, "we would make a chemistry course which was a lot more interesting."

Crosby would certainly agree. In his appeal for an invigoration of undergraduate chemistry, he is calling for a look at the entire content of what is taught. He notes that students are very impressionable, soaking up information from newspapers, television, and elsewhere. "They soak up the acid rain problem," Crosby says. "They don't know what it is. They know there is one. They hear about the ozone hole. They hear about recycling. They hear about the rain forests disappearing. And they don't really understand it. And they want to learn something about those things. And we cleverly manage not to teach them anything about it in our courses."

Likewise, Crosby continues, "they're interested in their own bodies. They're interested in drugs. They're interested in AIDS. They're interested in genetic engineering. They're interested in what photosynthesis is. And we cleverly in our beginning courses avoid mentioning anything like that because it's too damned interesting."

The result, Crosby says, is that students are turning away because they don't really see anything relevant. "It is relevant. And we know it's relevant. But they don't know it's relevant. We're requiring them to know the bridges to their ordinary lives, and we're not building them for them."

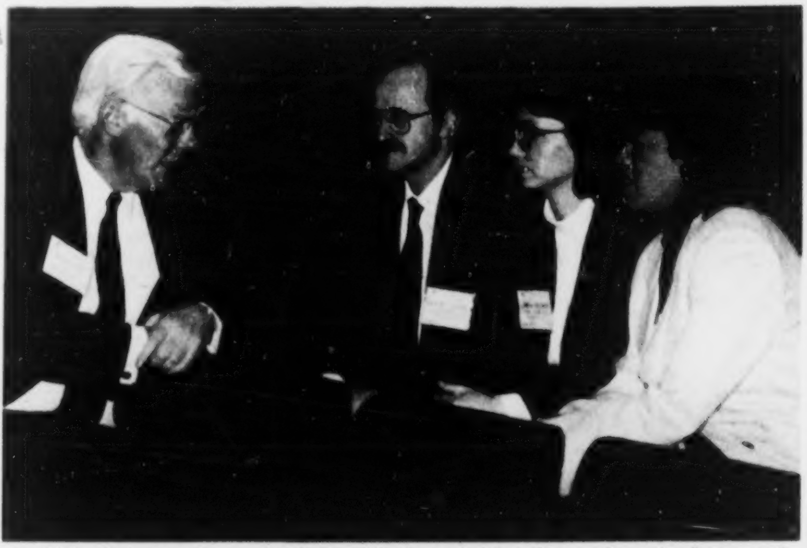
Lab operations also under the microscope

Curriculum isn't the only target of critics of the system. Laboratories come under the gun as well. The poor physical environment of the laboratories is a problem, says Lagowski. The problem, he points out, is how to do the requisite laboratory work for, say, 22 cents per student. "You know," he says, " we've let ourselves get into that position. We have let the nebulous 'they,' who in some instances is 'us,' get us into that position."

As a result, Lagowski says, "the place where students will do our science is generally a shambles—a physical shambles, an intellectual shambles, a shambles in general. And it's not surprising that a student can't really figure out what the point of anything is."

"Laboratories are stultifying," declares Crosby. "They're uninteresting. There's too much emphasis on principles and not enough on colors and sounds and explosions and smells."

There's not enough there that can stimulate the imagination of students, Crosby maintains. "Maybe for



Carbide chairman Kennedy chats with (from left) staff members Anthony and Linda Vecere and **Technicians Today** *editor Elizabeth Crawford-Harrison* us those principles are very interesting. But for a student who is just going into the field, that person doesn't have enough phenomena to hold onto to be able to hang the principles on."

As an approach to revitalizing the way general chemistry is taught, Lagowski appeals for creation of an ambiance where "we will essentially empower faculty to help students learn, and empower students to learn." It's an ambiance, Lagowski says, where learning will become more active. That means, he says, lectures should be fewer. Books should be thinner. Examinations will be different. The curriculum will become more laboratory-oriented. ("That's the heart of our science. . . . Chemists make things.") And laboratories will be more flexible.

"That's the ambiance," says Lagowski. "That's the ambiance in which a renaissance can occur. And for those who have a historical perspective, that is the ambiance from which we came. And somehow we have arranged for ourselves—administratively, resourcewise, whatever—to go away from a very successful ambiance. And I think it's just wrong. And we somehow have got to figure out how to get back to the future."

More than just introductory courses in chemistry are currently in the thoughts of chemical educators. For example, California Institute of Technology chemistry professor Harry B. Gray notes chemistry is in a dynamic period, a period of tremendous change. The basic paradigm of chemistry has changed, he says, and educators are faced with responding to that somehow in chemistry education and chemistry teaching.

As Gray sees it, the old paradigm was based on the traditional subdisciplines—physical chemistry, inorganic chemistry, organic chemistry, analytical chemistry, and the like. The four operations that have now taken over, he says, are chemical synthesis, chemical biology, theoretical chemistry, and experimental chemical physics.

"These are the four areas that I see people working in today," Gray says. "And I think that the educational establishment somehow has got to respond to what's going on in chemistry, so that what's being taught to freshmen and sophomores and juniors—majors and nonmajors alike—will reflect what's really going on now."

What's at stake, Gray says, is whether the words chemistry and chemical will remain. "Chemistry will be with us forever, and chemicals will be with us forever," he says. But what is at stake "is whether the chemistry group—our group—will in fact call the shots in education." The chemical community, he observes, is now engaged in an interaction with two other communities: materials and engineering on the one hand, and biology on the other. "The question now," he says, "is will the materials and engineering community be teaching our subject or will we; will the biology community be teaching our subject or will we. That's what we have to address."

Gray notes that change is going to be very difficult. But if he had his way, he says, he would redesign the whole curriculum now, starting with chemical synthesis as the first course, and concentrate on hands-on work in the first year. "I'm talking about a new level of hands-on work in the first year," he says, "built around synthesis and the structure and characterization and analysis of the molecules and other substances."

Hawkes (left) and Gray call for curriculum to reflect what chemists do in today's world

Beyond the level of concern over curriculum there is the issue of teaching versus research, the interaction of which is of increasing concern to many. There needs to be a balance between teaching and research, Crosby says. It's been badly out of balance for a long time, he contends, because of the reward system.

"The reward system is like the weather," Crosby says. "Everybody talks about it but no one does anything about it."

The result, he maintains, is that students perceive that university professors are haggard and worried about their careers. "They are being asked to be entrepreneurs. They are being asked to get large amounts of money to support overhead. They are being asked to write grants successfully. They are being asked to finance their own salaries. They are being asked to do all these things. And then they ask the question, 'If I'm going to go through all this, why don't I just go out into industry and make more money?' "

Crosby adds many professors are thus portraying role models of the wrong type. The students see it and react to it. "They are," he says, "much more impressionable than we give them credit for. And they're wiser."

Crosby's remarks echo those of Stanford University president Donald Kennedy. In an address to the Stanford Academic Council in April, Kennedy too called for a better balance between teaching and research.

"The joint product character of our enterprise has long been a source of strength to us," Kennedy said. "Teaching and research are both important, but the relative weight has shifted over time, as the relatively new term 'research university' suggests. It is time for us to reaffirm that education—that is, teaching in all its

Sigma Xi: an interdisciplinary view of undergraduate science education

When Sigma Xi, the scientific research society, convened an interdisciplinary National Advisory Group of 35 individuals at Wingspread in Racine, Wis., a year ago, it presented the group with two charges: Explore the nature and quality of undergraduate education in science, mathematics, and engineering; and identify the significant topics and issues that should be addressed in charting policy for undergraduate education in science, mathematics, and engineering.

The Wingspread meeting brought together representatives from the sciences, mathematics, engineering, medicine, economics, communications, sociology, psychology, philosophy, education, university administration, government, scientific societies, and other areas. Anna J. Harrison, professor emeritus of chemistry at Mount Holyoke College, South Hadley, Mass., and a former president of the American Chemical Society, chaired the meeting. Describing it at the ACS national meeting in Boston, she noted a "unanimity in discussion that I had not anticipated. In fact, the unanimity was so high, it was somewhat frightening."

An interdisciplinary group is important, Harrison says, because a group of that sort raises generic issues, issues that are common to all the sciences, not just issues that might have been thought specific to chemistry. That sort of group, she adds, also highlights the synergism among science, mathematics, and engineering.

That synergism is important, Harrison stresses. It is important, she says, that students who will not become professional scientists but will be that great mass of the public "understand that it is the whole group that makes the advances, not just chemistry or not just physics or something else."

The group first agreed upon a statement of the missions of undergraduate education. The reason for a mission statement, Harrison explains, was that if the group intended to explore the nature and quality of undergraduate education, it was necessary to have agreement on what that education was supposed to accomplish. The group agreed that departments of science, mathematics, and engineering have four missions that include encouraging and enabling undergraduate students:

- To pursue careers in science, mathematics, engineering, and related endeavors; careers in school (kindergarten through 12th grade) science and mathematics education; and careers in scientific and technological aspects of law, mass communications, and management.
- To discover the nature of science, mathematics, and engineering.
- To discover the aesthetic and human dimensions of science, mathematics, engineering, and technology (the order and beauty of many natural systems and many products of technology; the ingenuity of the human mind in creating models to rationalize the properties of systems and in creating technological options for the production of goods and services and the resolution of societal issues.)
- To become informed participants in the democratic processes through which value-laden issues involving science, mathematics, engineering, and technology are resolved.

Harrison notes that all the personnel pipeline concerns are focused on the first part of the first mission. As for the second mission, she says it may seem a little queer to include it, but she also says she sometimes wonders if some graduates in chemistry know what the nature of science is—that is, not a body of knowledge but a process of investigation.

According to the advisory group in its report, evidence is mounting that undergraduate education in science, mathematics, and engineering is not fulfilling its missions. For example, it notes, "More than 50% of freshmen intending to major in science, mathematics, or engineering fail to complete bachelor's degree programs in these fields, to say nothing of the many future teachers, communicators, managers, lawyers, political activists, public officials, and socially concerned citizens who are rendered permanently allergic to these fields by unfortunate experiences in introductory courses." The group says the crisis applies both to science, math, and engineering majors and to students majoring in other fields.

The advisory group identified seven fundamental topics that it believes need to be addressed. Harrison notes that topic seven—promises and special needs of traditionally underrepresented groups in science, mathematics, and engineering—is a separate issue. The other six, in order of significance, are:

- Quality of instruction. "Undergraduate education," the group says, "is trapped in an infrastructure that rewards those who devote their resources to research and denies those same rewards

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forms—is the primary task and that our society will judge us in the long run on how well we do it."

Perhaps it remains for Alice J. Cunningham, chemistry professor at Agnes Scott College, Decatur, Ga., and a member of ACS's Committee on Professional Training, to put a final gloss on the problems of undergraduate chemical education. Noting in another context that funding isn't the only problem in bringing about the changes being discussed, she also points out that when she was a student, there was a 180-day school year. Now, she says, the academic calendar has been pared. Semesters have been cut. "Do your mathematics," she says, "and you will find that we have lost six months of intructional time in a bachelor's program."

This group of concerns addresses questions raised by the issues of the science personnel pipeline and the place of chemistry in higher education. But as such they are only a part—though an integral one—of a much more extensive concern about science education and about science literacy of the public in general. And it is this broader concern that has in recent years generated so much of the report writing and, indeed, a great deal of activity.

At the ACS meeting, Shakhashiri provided a philosophical underpinning for the concerns involving science education in general. "Our literacy in science and mathematics," he states, "reflects our values as a society—what we care about, what we believe in, how we

Harrison: values key part of policy-making

to those who devote a significant portion of their resources to fulfilling the mission of undergraduate programs—to encourage and enable undergraduate students to achieve. The practices of many segments of society (including the research community, college and university administrations, state and federal governments and their agencies, and private foundations that fund research) have created and reinforced the value system that produced and sustains this dichotomy."

- Quality of curriculum. "The student perception of the undergraduate curriculum in science, mathematics, and engineering and the faculty perception of that same curriculum are by no means congruent," the advisory group says. "Many freshmen view entry-level courses in science, mathematics, and engineering as inaccessible—or if accessible, unrewarding to them." The group identified entry-level courses in science, mathematics, and engineering as "watersheds" that determine both the place of science, mathematics, and engineering in the lives of those who go to college, and the vitality of undergraduate programs in these disciplines at colleges and universities.

- Quality of the human environment. "Large classes," the group says, "impose student/faculty ratios that often make the faculty inaccessible to all but a few students and, at best, students view the human environment as impersonal. The common practice of using entry-level courses as barriers to protect more advanced courses from all except the most able and the most committed still persists and, at worst, students view these classroom environments as destructive and hostile."

- Quality of the physical environment. Recognizing the value of adequate libraries, laboratory facilities, and instrumentation, the group focused its attention on the aspects of the experience within that physical environment that it says are truly educational to students. High value was placed upon the student having hands-on experience with the investigation of phenomena. "Through this experience," the group says, "the student has experience with critical thinking, planning, analysis, and synthesis, and the opportunity to discover the integrity of data, the uncertainty of measurements and, through these, the development of understanding of the powers and limitations of science and engineering."

- Accessibility and flexibility of curricula essential for student mobility. The faculty, the group says, may view an undergraduate major as a carefully sequenced program of courses. To the student, a tightly sequenced major in a discipline may be perceived as a one-way express road with an entrance ramp in the freshman year and an exit ramp at the completion of the major in the senior year—no interchanges along the way. "The student who wants to participate in charting his or her undergraduate education on the basis of experience and developing interests needs a map with interchanges to major sequences in other disciplines," the group adds. "If interchanges between disciplines do not exist, attention should be given to creating them."

- Attitudes and perceptions of students, faculties, administrations, and the public. The group notes that in the presentation of the preceding five significant topics, issues related to attitudes and perceptions have arisen repeatedly. "In charting policy for undergraduate education in science, mathematics, and engineering," it says, "bringing about changes in attitudes and perceptions must be a part of any effective policy."

Harrison says if she could change the list now, she would add "values" to the last topic to make it "attitudes, perceptions, and values," and she would move the topic to the top of the list. Much of the talk concerning education at the ACS meeting, she noted, was talk about attitudes, perceptions, and values, which she found promising. A few years ago, she says, these words couldn't be used. Anyone using these words would have been laughed out of the room. "You just couldn't discuss it."

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treat each other, and how we treat our environment." He stresses that by science literacy, he means literacy for all people. "If you care about the quality of life in our society," he says, "then you will care about joining forces and seeing to it that all segments of our society are enabled to fulfill their human potential."

Shakhashiri believes those in the science-rich sector of society owe something to the science-poor sector of society. By science-rich sector he means colleges and universities, parts of industry, and the national laboratories; by science-poor sector, everyone else.

It is fairly well understood, and even agreed to, Shakhashiri says, that the science education battle is lost not in the sophomore year in high school but earlier. And that's why NSF has been heavily focusing on middle school and elementary school levels.

"However," Shakhashiri insists, "that's where we don't have chemistry courses, that's where the disciplinary demarcation lines disappear, and that's where we, as chemists and chemical engineers, have got to show up on that playing field and see to it that there is quality education at the middle school level and the elementary school level in science."

Shakhashiri admits he is often accused of preaching to the choir. If so, he says, it's because "I want the choir to sing. And I want the choir to sing out loud and in harmony." He even supplies some lyrics, hurling challenges to various sections.

For example, to ACS and members of ACS, he urges: Expand the efforts of the education division and strengthen the operations of the division of chemical education; widely broaden national and local section programs ranging from National Chemistry Week to recognition of high school chemistry teachers; work with middle school and elementary school teachers; help lead national curriculum developments at the undergraduate level; take the "Procter & Gamble" approach (five or six high-quality soaps for the market to choose from) to curriculum and put out five or six alternatives in the curriculum area so that school systems and colleges and universities can choose from among them; support and participate in the AAAS Project 2061 and a National Science Teachers Association (NSTA) companion project called Scope and Sequence; continue to inform Congress about national needs in research and in education; update the ACS's 1984 Yankwich Report ("Tomorrow: The Report of the Task Force for the Study of Chemistry Education in the United States"); and help to influence other organizations "to see to it that the intellectual prowess of this nation devotes a fraction of its effort to deal with those science education issues at all educational levels."

To industry, he challenges: Expand support for major reform efforts in science education, not only supporting Presidential Young Investigators awardees but also undergraduate faculty and high school teachers; participate in forming alliances and coalitions with school systems and with institutions of higher education, seeing to it that there are standards in the school systems and that those standards are achieved, and "seeing to it that no school in the U.S. can use any excuse for not offering a chemistry course and not offering a chemistry course with a laboratory component;" help infuse ideas into other business organizations, such as the local Chamber of Commerce, so they can continue the interest they now have in solving the problems of science education; continue to influence national policies in science and science education; and be responsible for informing the public about chemistry, about chemicals, their benefits, their safe handling, and their potential hazards.

To colleges and universities: Be ready and prepared to take on the responsibility of a huge influx of funds that "there is little doubt in my mind" will be coming from the federal government and from the business sector in the next five to 10 years to colleges and universities to address the problems in science education at the undergraduate and precollegiate levels; address research versus teaching issues to achieve an appropriate balance; stop, immediately, taking pride in weeding out so many students at the freshman and sophomore years ("We are in the talent development business; we are not in the business of weeding out students"); and look at the outcome of the educational process, asking what it means to be the holder of a bachelor's degree from a given institution ("If concern about curriculum is not a primary concern of the faculty, I don't know who else is going to be concerned about it").

To the federal government and, specifically, NSF: Develop a national strategy with a set of goals and standards, goals with regard to student achievement, teacher qualifications, the environment for learning, and the quality of the curriculum.

As to the strategic role of NSF in all of this, Shakhashiri says, it adds up to science literacy for all students. "We want the best preparation for careers in science and in teaching science," he says. "We want to increase representation. We support experimentation. We're interested in generating change—fundamental, comprehensive, systemic change, not incremental change. Incremental change is not going to work. When you have incremental change the sum of the parts does not add up to the whole. We want to assist in the implementation, and that's what the NSF funds are for, to assist in the implementation and see to it that we have a national major strategic effort that can solve the problems that face us."

Goals for turn-of-the-century set by governors

Many of the efforts called for by Shakhashiri, or parts of them, are, of course, already under way. The federal effort, for example, received a big boost from President Bush and the state governors last October. At an education summit held in Charlottesville, Va., the President and governors declared, "The time has come, for the first time in U.S. history, to establish national performance goals, goals that will make us internationally competitive." That said, they enunciated six national education goals:

- By the year 2000, all children in America will start school ready to learn.
- By the year 2000, the high school graduation rate will increase to at least 90%.
- By the year 2000, American students will leave grades four, eight, and 12 having demonstrated competency in challenging subject matter including English, mathematics, science, history, and geography; and every school in America will ensure that all students learn to use their minds well, so they may be prepared for responsible citizenship, further learning, and productive employment in our modern economy.
- By the year 2000, U.S. students will be first in the world in science and mathematics achievement.
- By the year 2000, every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.
- By the year 2000, every school in America will be free of drugs and violence and will offer a disciplined environment conducive to learning.

It is these goals that are now the engine driving federal government efforts in science education. They underlie, for example, the recent program announcements of NSF's statewide systemic initiatives and of the Department of Energy's science education initiatives.

Some people snicker at the goal of making the U.S. first in the world in science and math by the year 2000, Shakhashiri notes. But, he points out, it's a remarkable accomplishment for the President and governors to agree on the goals. "What we have to do," he says, "is join in making a very serious attempt to achieve that goal. Otherwise, it will become an empty goal." Indus-

Samuel (left): middle school is last chance to hook child's curiosity of natural world. Gardner: must not lose chemistry during early school years

try is one group that is taking the challenge seriously. Numerous specific activities sponsored by individual companies are adding up to a ferment of activity in the industrial world. But the business sector is also addressing science education issues more generically, as business.

Keynoting an ACS Corporation Associates symposium in Boston on the topic of industrial initiatives in precollege science education, Union Carbide chairman and chief executive officer Robert D. Kennedy outlined the approach business is taking. President Bush, he notes, met with business leaders last fall the day before the governors' conference and challenged them to become involved in a truly common effort for education reform. The result, Kennedy says, is that a separate section of the Business Roundtable organization has been established for each state. Kennedy heads the Connecticut section.

The Connecticut section, which met just recently, has set three goals. The first goal, at the state level, is to establish a vision of what the educational system should be. It involves, Kennedy says, comparing the situation that exists now with what it should be. It involves defining what a person should know who's in grade eight, 10, and 12—what constitutes an adequately educated person. And the goal must be defined by global standards, Kennedy says, because American students are competing with students from all over the world.

The second goal is for the business group to push its point of view on policy issues. For example, Kennedy says, of the 20 cities in the U.S. with the most severe inner-city education problems, three of them are in Connecticut. So one of the policy issues being tackled, he says, is determining what kind of resources are needed in the worst places, so that students there can compete with students in the best places.

The third goal is to sound the alarm generally. Change isn't going to happen, Kennedy says, unless people are really dissatisfied with the situation that exists. They have to be told what's wrong, why it's wrong, and what the implications are. Then, he adds, business must develop partnerships with parents and students, and with educators and teachers and other people who want to improve education.

Kennedy doesn't mince words in describing the situation as he sees it: "We have an education crisis of epic proportions in this country. It's been building for 40 years. It's not going to be solved in anything less than 10. And most of our citizens aren't aware of it, concerned about it, both or either."

Strong justification for Kennedy's views comes from the Union Carbide task force study made last year. Kennedy had appointed the task force and had charged it with defining the issues in education and the corporation's role in their solution. The resulting report, he says, "has become a blueprint for our corporate involvement in trying to build a world-class education system." The company, he says, is committing years of personal effort and corporate resources because it doesn't believe the problem can be solved with Band-Aid solutions.

Business people don't have all the solutions about what to do, Kennedy admits. But, he argues, they do have experience in such areas as setting goals and measuring performance. And they do have some idea about requirements for the jobs of the future.

Kennedy has found a lot of people are already becoming nervous about business getting too involved in education. He noted, for example, at a recent education conference parents and school boards expressed the fear that the only reason business is interested in education is because it wants a quality work force—that business looks on education as a trade school.

"Wrong," says Kennedy. "We've got to turn out world-class educated kids by grade 12 just so they can be qualified citizens—not fodder for business—just qualified citizens."

Kennedy thinks that outcomes, results, are a very appropriate role for business executives, for parents, for citizens. "We have to measure what the product is. And measure it against the competition."

In education, Kennedy explains, the product is the student. The consumer is the parent. And the consumer is the taxpayers who foot the bill for public educa-

Union Carbide task force views business as a catalyst for change in education

Many companies have programs of one sort or another focused on education in general or science education in particular, and some of the programs are fairly extensive. However, Union Carbide has begun what may be one of the more involved efforts.

In December 1988, Carbide chairman and chief executive officer Robert D. Kennedy established a corporate task force on education to study elementary and secondary education and to report to him on an appropriate role for Carbide in addressing that issue. In the report that resulted last year, the task force notes that although it recognizes learning is valued in its own right, its report focuses on how well the education system is meeting the economic interests of the country and the company.

Not very well at all is the answer found by the task force. The task force's report sets the stage with a statement that is an adaptation from "Workforce 2000," a recent Hudson Institute study on work and workers of the 21st century: "Our vision: Every child who reaches the age of 17 can read sophisticated materials, write clearly, speak articulately, and solve complex problems requiring algebra and statistics. Unconstrained by a shortage of competent, well-educated workers, American industry is able to expand and develop as rapidly as world markets allow. Boosted by the productivity of a well-qualified work force, U.S.-based companies reassert historic American leadership in old and new industries, and American workers enjoy the rising standards of living they enjoyed in the 1950s and 1960s."

Concludes the task force: "We will not fulfill this vision without fundamental changes in our elementary and secondary education systems."

In pursuing its charge, the task force researched the issues for some six months, reviewing a wide variety of publications and documentaries and conducting numerous in-depth interviews with educators and education leaders. In April 1989, it hosted a forum at the Union Carbide Center in Danbury, Conn., on emerging education issues. Fifteen education and business leaders were presenters and panelists for the forum, which drew together Union Carbide representatives from key community locations, local school superintendents, and others from Carbide communities, as well as the corporate task force members.

Although the task force's conclusions about the poor state of education are similar to those of numerous other studies, its deliberations brought a somewhat different perspective to bear on the education problem. As a result of its research, the task force says it determined there is a critical problem and it is much misunderstood. The problem, it says, is that schools have remained the same, while the economy and society have changed and the country's educational needs have become greater. The result is a relative decline in school performance.

The U.S. school system, the task force explains, was designed for an agricultural economy, and the structure hasn't changed for more than 100 years. At that time, it wasn't necessary or even desirable to highly educate everyone. But that is the goal today, and the outmoded system that exists is incapable of meeting modern needs.

The task force notes four trends that are converging toward trouble: Population growth rate is declining, and the number of 16- to 22-year-olds entering the work force is shrinking; jobs require high levels of knowledge and skills; student achievement hasn't increased significantly and by some indicators has sharply declined over the past 20 years; and minority students, who are least well served by the school system, are the fastest growing segment of the population.

A larger portion of students must be educated better if the country's labor needs are to be met, the task force says. This calls for increasing student achievement levels across the board. But inherent limitations in the school system prevent it from living up to the challenge.

"Without improvements," says the task force, "we have, at best, an un-

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tion. And the consumer is U.S. society in general. "There are lots of consumers of education," he says, "and the product they're all getting is not good enough."

The problem, in Kennedy's view, doesn't lie with the teachers. It is the educational system itself that's at fault, he charges. In that regard, he quotes Albert Shanker, president of the American Federation of Teachers: "If I worked in an office that was organized the way secondary schools are, I'd be given a desk, and there would be 25 or more other workers sitting around me doing the same work. I could never talk to them. There would be a boss to tell me what to do. Every 50 minutes a bell would ring, and I'd go to another room with 25 different people to do a totally different kind of work—with a new boss. I'd be encouraged to make mistakes instead of checking my work with someone sitting next to me—because that would be cheating. And I'd be humiliated by having my mistakes called to the attention of the entire office. . . . It's not surprising that no office in the world is organized the way our schools are."

Kennedy calls for nothing short of revolutionary change, complete restructuring of the system, because everything is interrelated. "The kinds of teachers we get," he says, "are related to the kind of reward structure and professional environment we provide for teaching. That's related to the way we allocate resources and responsibilities at the schools. That's related to the way we finance and structure education. That's related to the politics of education. And all that's related to the kind of motivation students receive from their peers and from their parents. And whether inner city kids are even prepared at age five or six to start into the system."

So, he concludes, "If we want to do it right, we have to do it all. What we need is nothing less than revolutionary changes in the way we educate our children."

Kentucky is an example of a state taking this approach, Kennedy says. Last month, he points out, the dereducated population which keeps this nation from realizing its highest economic potential. More likely, we have a threat to our international competitiveness and to our standard of living." The task force called its report "Undereducated, Uncompetitive U.S.A."

The task force points out that with some 16,000 independent school bureaucracies in the nation with about a century of experience invested in the status quo, the system is resistant to change, and the momentum cannot come from inside. Educators with vision, the task force says, are asking for help from without.

This is an appropriate and critical role for business to play, the task force says. More than $180 billion is spent annually on education. Business, it argues, has a major investment in the system, through tax dollars, and a major stake in the output. Business therefore has an obligation to make sure the system performs optimally.

The task force recommends Union Carbide support and initiate programs designed to bring down the barriers to school reform and to stimulate change. The efforts, it says, should be directed externally, to the general public, and internally, to Carbide employees. It recommends four cornerstones to the efforts:

- A powerful information campaign to change public attitudes toward education. Carbide, says the task force, would take a leadership role in coordinating a massive effort to raise public expectations similar in scope to the national acquired immune deficiency syndrome and smoking awareness efforts.
- A leadership role in creating a national coalition to establish educational goals. (The task force notes since its report was written, the National Governors Association has taken the lead to establish national goals and that Carbide's activities aimed at educational goals will be coordinated with this effort.) "Education today," says the task force, "is like an industry unclear about its product and, therefore, unable to practice quality control."
- Bold demonstration programs of school reform in two Carbide communities. Union Carbide would sponsor models for major school restructuring, and results would be shared with the nation. Models, the task force says, would be built around principles of teacher autonomy, parental involvement, school-based management, raised expectations for academic performance, clear goals and measures of accountability, and greater "results orientation" rather than "process orientation." There would be a mentor component in which active or retired Carbide volunteers would pair up with "at-risk" students and provide support and encouragement.
- A rigorous and high-profile internal information program directed to raise employee awareness of the education issue and to encourage parents to become more active in their children's schools.

Besides these four "cornerstones," the task force identified five additional programs that would complement and round out the involvement. The first of these would be incentive programs for teachers in Carbide communities to become "board certified." Second, the task force envisions political support of legislative changes in key Carbide states and at the national level that favor school reform, such as deregulation of education, alternative routes to teacher certification, and full funding of Head Start programs.

Third, an internal company program would facilitate a mid-career switch to teaching for interested Carbide employees and/or would allow for teaching assignments with simultaneous Carbide responsibilities.

A fourth complementary program would be financial support and promotion of programs to enhance math and science teaching skills at the elementary level in key Carbide communities. And the fifth would be financial support of programs to address potential teacher shortages and to reform teacher preparation programs.

"The issue of public education," the Carbide task force goes on to say, "deserves bold, meaningful action on the part of Union Carbide or none at all. To dabble in the problem will not significantly improve school performance and will not be an efficient use of [Carbide] resources. To make an impact, [Carbide's] commitment to the recommended projects must be long term—not less than 10 years."

General Assembly there enacted what he describes as the most sweeping education package ever conceived by a state legislature. The new system in Kentucky, which will be adopted over a five-year period starting in January, will end state control of local schools. By 1995, the state's 178 school districts must surrender control of local school budgets and educational programs to boards of three teachers, two parents, and the principal. All of Kentucky's current education regulations will be repealed, and the state's Education Department will get out of the regulating business. Its role will be to set learning goals for each subject and grade and to develop ways to assess whether students are meeting them.

Restructuring the aim, not finding a quick fix

As Kennedy notes, "This is not a quick fix. It's a complete restructuring." Kennedy is not alone in calling for such restructurings. Comprehensive, fundamental, and systemic are words being used more and more to describe what many see as being needed in approaching the problems not just of education generally but of science education specifically. It is, for example, the concept behind the major new NSF program of statewide systemic initiatives in science, mathematics, and engineering education.

NSF intends its role to be one of providing funds to catalyze a much broader effort. For instance, its solicitation for proposals states that an important consideration in the awarding and continuation of funding will be the degree to which proposals incorporate the use of state, local, and private resources with funds from NSF and other federal sources.

The NSF solicitation notes 10 components that make up what it considers to be covered by the term systemic: organizational structure and decision-making; provision and allocation of resources; recruitment and preparation of those who teach; retention and continuing professional development of teaching and nonteaching personnel; curriculum content and learning goals; delivery of instruction, including the use of educational technology; assessment of student achievement; facilities and equipment; articulation within the system; and accountability systems.

The program will provide awards in the first year to four to eight states for $1 million to $2 million, totaling $5 million to $10 million to each receiving state over the life of the project, which may be up to five years. Letters of intent to submit proposals are due July 9, with formal proposals due Oct. 15.

Meanwhile, at more local levels, a bewildering array of programs have come into existence. Many companies—chemical and otherwise—have mounted programs designed to stimulate students and provide training and encouragement for teachers. For example, Dow Chemical has worked with NSTA every summer since 1986 to bring high school teachers from school districts across the country to Midland, Mich., for a two-week training workshop in Dow's central research laboratories. The company has also created a program called Touch Tech that reaches some 40,000 students a year to expose them to modern science through seminars for students, videotapes, a chemistry lab for children, and a mentor program.

Du Pont provides another example. It has since 1984 held summer workshops for high school teachers designed to raise the quality of precollege science teaching and foster industry/school partnerships in communities near Du Pont plants. The workshops provide an introduction to polymer technology and biotechnology through lectures, hands-on laboratory experience, and field trips and include an active followup program with graduates to build a continuing relationship.

Still another program variation comes from W. R. Grace & Co. In 1988, the company's Washington Research Center and Atholton High School, both in Columbia, Md., announced the formation of an educational partnership based on the theme of "improving teaching and learning through technology." The goals are to interest students in careers in science by exposing them to real-life scientific research and to use the latest in technology to enhance student learning at all levels. Key elements of the partnership are college scholarships for students pursuing studies in science; a mentoring program; funds provided to the school for computers and audio-visual equipment, including a satellite dish for use in teaching; joint clubs between the school and Grace; and summer employment for two Atholton teachers at the research center as well as an on-going relationship between representatives of both organizations.

These are just a few of the many corporate activities and program variations now multiplying around the U.S. Adding to them are efforts from the government sector such as those of the national laboratories.

Last month, the Department of Energy launched a high-profile effort aimed at precollege math and science education that involves a group of national laboratory initiatives. Besides achieving the direct benefits of the programs, DOE believes that its assortment of laboratories, facilities, and 48,000 scientific and technical personnel give it a unique opportunity to act as a role model and catalyst for other agencies and organizations. The DOE laboratories and facilities are already heavily active in science education efforts, but the new initiatives broaden the scope. A few of them:

- A program, called Options, from Pacific Northwest Laboratory that connects middle school students and teachers with PNL scientists. The program focus is on schools with a high percentage of Hispanic, Native American, or black students. With staff scientists as mentors, teams of students and teachers meet together on a regular basis.
- A program called the Bay Area Science & Technology Education Collaboration (BASTEC) that involves Lawrence Berkeley Laboratory; Lawrence Livermore National Laboratory; Sandia National Laboratory, Livermore; and Stanford Linear Accelerator Center. The goal of BASTEC is to improve the teaching and learning of mathematics, science, and technology, from kindergarten through the 12th grade, through a collaboration of the Oakland Unified School District with educational and research institutions, community organizations, national laboratories, and businesses.
- A rural teacher training program from Los Alamos National Laboratory and Sandia National Laboratory. It is a teacher enhancement program for middle school teachers in the rural areas of New Mexico, with a large Hispanic population. Included in the program are a summer institute, academic year followup workshops, and classroom visits, with teachers required to establish a chapter of Mathematics Engineering Science Achievement (MESA), a program designed to encourage minority students to pursue careers in science, mathematics, and engineering.
- Science & Mathematics Action for Revitalized Teaching (SMART), a partnership of school systems and national laboratories formed in Tennessee. Designed to enhance education in science and mathematics in Chattanooga and Roane County schools, the partnership includes Oak Ridge Associated Universities, Oak Ridge National Laboratory, Roane State Community College, the Chattanooga public schools, and Roane County schools (including the two systems, Roane County and Harriman). The SMART program includes ORNL-based summer research participation programs and workshops and a summer science camp for students.
- A Science Explorers Program in Chicago that involves Argonne National Laboratory and Fermi National Accelerator Laboratory, the Chicago public schools, and a group of Chicago institutions involved in science education, called the Explorer Partners. Centered on a series of videotaped TV shows created by area TV anchorman Bill Kurtis that features scientists using modern tools to explore the world of modern technology, program activities include laboratory demonstrations, class meetings with staff scientists, and discussions concerning career opportunities. "Mentor groups" of retired scientists will be utilized to provide technical expertise and program coordination.

That so many of the industrial and government programs target the middle school level isn't coincidental. The importance of reaching children in grades five

Dow Chemical photo

Dow researcher works with student in company's Touch Tech program

through eight, or five through nine, depending on the particular school system, is underscored by Patricia L. Samuel, director of freshman programs at Boston University.

"This is our last chance to hook onto children's innate curiosity about the natural world," Samuel says. "Once they get past the eighth or ninth grade, if they don't like science at that age, they aren't going to like it. So this is really a last-ditch effort."

Program aims for better middle school teachers

Samuel was describing for the Boston ACS meeting a relatively new NSF-funded program at BU in the College of Liberal Arts' school of education called Program for Middle School Science Education. It is an undergraduate program designed to produce better-educated middle school science teachers. The first class of students has been graduated, and another group of seniors is just finishing up student teaching. There are also a couple of masters students who will be finishing soon.

The program is a two-year undergraduate or masters level program, Samuel explains. "An essential ingredient" of the program is that the students are asked to be good enough in science and interested enough in science to be willing to major in it. Most of the students at this point have been biology majors, Samuel says, although currently there are two chemistry majors. In addition to the major, the program includes six education courses plus student teaching.

Samuel explains that faculty from the science departments have been pulled together to design a two-semester interdisciplinary science course for students in the education program. Organized around the idea of products of evolution, the course is team taught—the first semester, for example, starts with astronomy and physics, then moves into some chemistry, followed by geology. The course helps to integrate all the disciplinary pieces.

Such an approach is necessary, Samuel explains, because teaching is not done by discipline in middle school science. It is simply science. "You look out at the world, and there is some phenomenon, and you try to figure out what makes it work."

It is at levels such as middle and elementary that the chemical community must take care to see that chemistry is not lost, warns Marjorie H. Gardner, senior research associate at Lawrence Hall of Science in Berkeley, Calif. For example, she points out that ACS has taken more leadership in the world of science education than any other professional society, at least within the disciplines.

But, she says, although there is a large amount of work going on directed at kindergarten through 12th grade, "we haven't thought very seriously yet about how we're going to participate in this restructuring of the curriculum and the teaching of chemistry from kindergarten level to the 12th grade level. And I would suggest that that's one of our new initiatives."

Representative of the type of restructuring Gardner is referring to is a new project under way in California known as the 100 Schools project. That's 100 high schools, she says, and each was invited to include a middle school. So that amounts to 200 schools that are engaged in attempting to restructure the science curriculum in a way that would lead to some chemistry being taught every year from grades seven through 12, not in grade 11 alone. The project, she notes, has great implications.

So, too, does a new thrust of NSTA for "science for every year for everyone." The idea is that science would become a part of the core curriculum in the same way that English is taught. It would no longer be an elective.

"This kind of program—science every year—has a lot of merit," Gardner says, "because if it becomes science for everyone every year, and chemistry is well represented, women and minorities are going to be in all those classes. They aren't going to be canceled out at an early age when they can't then follow the options of their interests as they mature. Furthermore," Gardner stresses, "the public at large should develop literacy—practical, useful knowledge of science that they can use in their everyday lives to improve their lives."

So, the assault of the three Rs on science education has begun. Reform, restructuring, and revolution are definitely in the air, but what specific effect they will have isn't yet clear. Nor is the amount of time it will take to solve the problems that exist. As Carbide's Kennedy notes, it's taken 40 years to get to the present situation. As Gassman points out, the solution is at least a two-generation one. ☐

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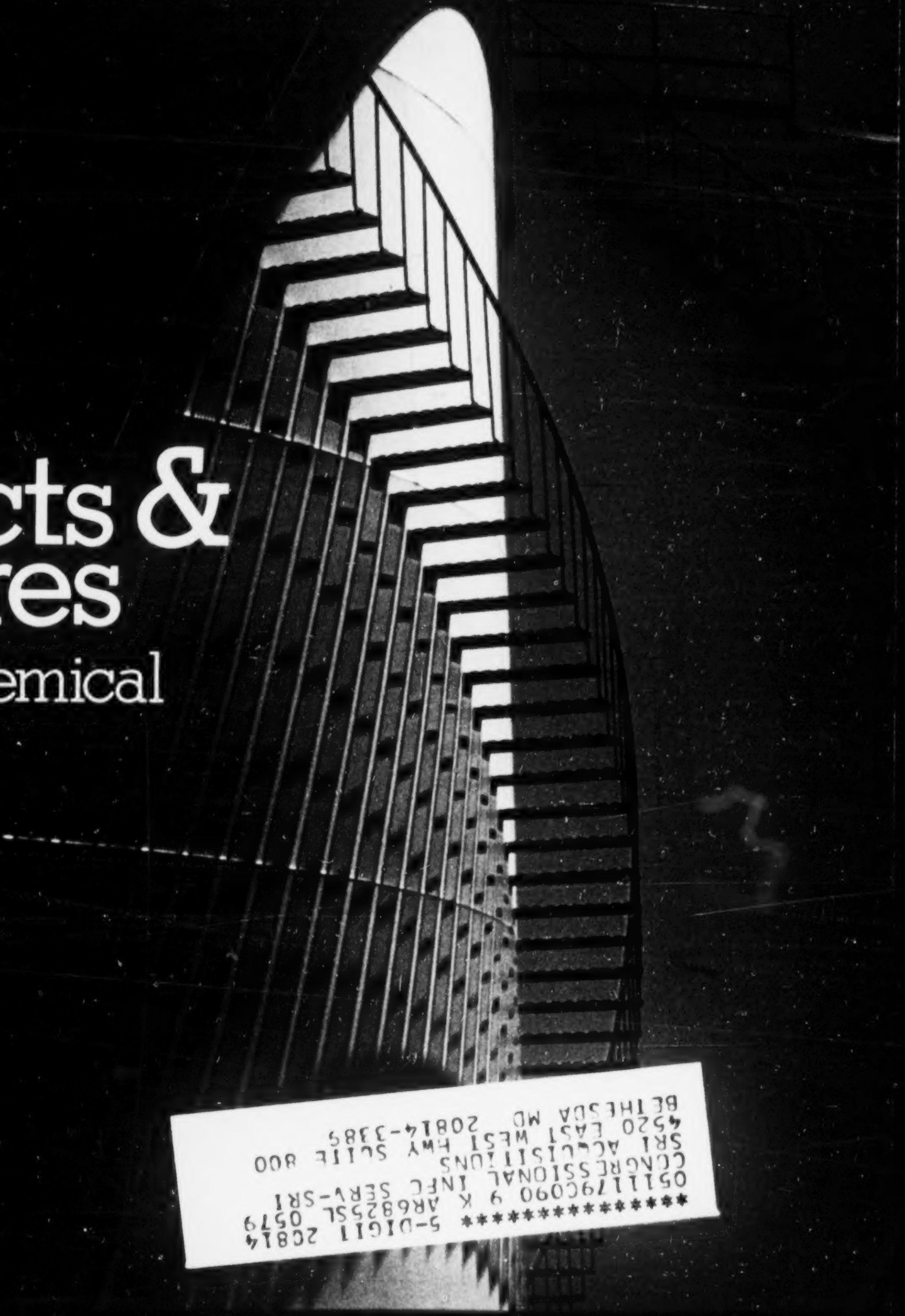

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News of the Week

- **Dialog Information Services files $150 million antitrust suit alleging ACS is using its "monopoly" over Chemical Abstracts Service's chemical information databases to seek control of on-line markets.** Page 4
- **Cold fusion continues to gather controversy as University of Utah president resigns under faculty pressure and university begins financial and scientific probe of its cold fusion research institute.** Page 5
- **Du Pont announces it is ending production of its acrylic fiber, Orlon.** Page 5
- **EPA issues rules controlling smog-forming volatile organic compound emissions from new synthetic organics plants and hazardous waste facilities.** Page 6

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Chemical production in Western Europe will likely grow a moderate 2.5% this year, according to CEFIC, slightly below the 3% rise expected in both gross domestic product and all manufacturing. **Page 9**

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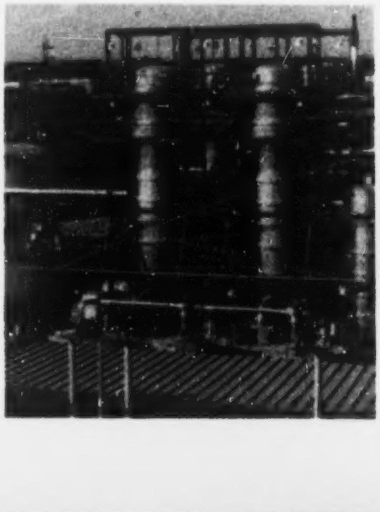
"**Biotechnology in Japan**" by Malcolm V. Brock touts that country's centralized, goal-oriented strategy toward development by government, academia, and industry. **Page 84**



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LETTERS

CHEMICAL SAFETY

Solvent extraction hazard

SIR: In his letter (C&EN, April 30, page 2) Ray E. Kelling describes the explosion of a 2-L separatory funnel this way: To a 1-L sample of well water acidified to pH 2 with phosphoric acid, 60 mL methylene chloride was added. Then the stopper was inserted, and before venting could be done the funnel exploded when it was inverted.

I am a chemist who has performed extractions like this one hundreds of times over a six-year period. Once, I had a similar experience because of a weak spot in the separatory funnel. To avoid explosions like this, I recommend three safety precautions: (1) Inspect the separatory funnel for weak spots or cracks before using it. (2) Use refrigerated acid for pH adjustment to avoid heating the sample. (3) Prerinse the funnel with methylene chloride before adding the sample to the funnel. This avoids excess pressure buildup when the 60 mL methylene chloride is added and the stopper is inserted.

Dean W. Gibbons
Analytical Laboratory
Detroit Wastewater Treatment Plant

Teaching science

SIR: This letter is a response to those of Lewis Schupp, Dana Chatellier, and Thomas Collet (C&EN, March 5, page 3). Each of these writers makes some valid points.

I am a Ph.D. physical chemist with what were common minors in the 1950s: physics and math. All I ever wanted to do was teach, and the Ph.D. was the union card. My degree was awarded in absentia the day my third child was a week old, so it was several years before I looked for a job. It turned out that what was available was an opportunity to teach general physics at the university where my husband was professor of chemistry. I have been teaching now for nearly 30 years—first elementary school science on educational television along with college physics, then for the past 20 years a physical science course designed to give elementary education majors a broad background, including laboratory experience, for teaching science and to promote science literacy among the business and liberal arts students. I teach a kids' science class on Saturday mornings, work in Olympiads and science fairs, visit schools with demonstrations, and am generally on call to promote the teaching and learning of science whenever I can.

As a result of my choice to teach, I will never be highly paid. I will never make full professor. Perhaps, I will have encouraged a few youngsters to become scientists and created a little bit of understanding of what scientists do on the part of the general public. I am happy with my choice.

However, it is neither fair nor reasonable to expect that generation after generation of teachers and scientists will choose their jobs solely for love when people whose contribution to society is much less important are much better paid. I agree with Collet that the situation must change, but I don't have any quick fixes. A recent letter to the British weekly *New Scientist* sheds some light on the problem, I think. The writer points out that although children enjoy science demonstrations and lessons, they do not identify with the scientists who present them. When they are asked what career they would choose, they opt for commoner things—from fireman to hairdresser to secretary to salesperson—not for following in the footsteps of the oddball who did the science demo. The letter writer comments that we must find ways to present science to youngsters as a useful and challenging career for ordinary people.

Schupp has some good ideas about how to do that, but they would be prohibitively expensive for most school systems to initiate. There may be alternate approaches, and I would like to suggest a few.

- Make the most of local institutions. Some school systems in cities that have museums have developed innovative curricula that make the most of the local museum's resources, whether by taking the children to the museum or bringing the museum's exhibits and personnel to the schools.
- Involve prospective employers. As science-based industries become more aware of the shortage of trained workers at every level, they will be more receptive to requests for funding well-designed programs administered either by schools or by community organizations. IBM is already investing both money and people in a big way in "Operation Smart," a Girls Clubs program aimed to interest girls who might not

CEFIC Expects Moderate Growth in Chemicals in West Europe This Year

Although destocking is slowing production, chemical growth will lag only slightly a 3% rise in both gross domestic product, all manufacturing

Patricia L. Layman, C&EN London

Growth in production in the chemical industry in Western Europe will likely be about 2.5% this year over 1989, predicted the European Chemical Industry Federation (CEFIC) at its annual meeting two weeks ago in Paris. That is only slightly lower than the expected increase of 3% in both gross domestic product and all manufacturing production.

Production slowed considerably in the second half of 1989 because of destocking, as companies ran down inventories. CEFIC analysts assume that further destocking will continue during the first half of 1990, as a result of low prices. Producer price increases will probably be below the rate of general inflation, reflecting the strong competition in the European chemical industry and the fact that prices for oil and other raw materials are expected to rise only marginally.

For the fourth consecutive year, according to CEFIC, West European domestic chemical demand in 1989 was the main driving force for the industry's sales. Exports rose 5.2%, but that was down from 7.6% in 1988, as unfavorable currency effects—primarily the weak U.S. dollar and Japanese yen—cut into export business. The weakening in exports is expected to continue, with growth in volume down to 3.5% this year, the federation predicts. As counterpoint, imports, which rose 9.7% in 1988, were up 9.9% last year; however, that growth is expected to taper off slightly to an expected 6% this year.

Metz: decade of communications

Overall, in 1989, chemicals continued as a positive contributor to the balance of trade in Western Europe. Exports less imports in 1989 were $25.8 billion, according to CEFIC statistics, roughly the same in local currency values as in 1988. The comparable number for the U.S. was $16.2 billion. Japan was a net importer of chemicals, with its imports less exports totaling $1.13 billion, an increase of 38% from 1988.

Statistics can make a simple, straightforward picture. But a complicated task for CEFIC at this annual meeting was to realign its industry executives who serve as president and vice president of the association. The hasty but dignified reshuffle was forced by the illness of the president-elect, Jean-Marc Bruel, of Rhône-Poulenc, who was scheduled to take over as president at the meeting.

As a result, Günter Metz, retiring president of Hoechst, was reelected president until January 1991, when he will be succeeded by new vice president Daniel Janssen, of Solvay. Janssen, who had been scheduled to succeed Bruel, will serve until June 1992, when he, in turn, will be succeeded by Jacques Puéchal, of Atochem.

The management reshuffle came, additionally, as CEFIC has embarked on a strategic planning mission, to chart "CEFIC 2000," developing for the federation "an international strategy that will take us beyond the confines of Europe and beyond the horizons of the immediate future," as Metz put it.

As the industry enters what he sees as "the decade of communications," it must ensure that CEFIC, its member national associations, and its affiliate member companies "speak to the outside world with a single voice. CEFIC must view its activities now on a truly international scale," Metz said, an indication of how much it has developed since its founding 18 years ago.

Besides the national chemical industry associations, it includes 43 individual companies as members of its Assembly of Corporate Associate Members, and more than 70 sector groups, special interest groups within the chemical industry. CEFIC itself is also a member of the International Council of Chemical Associations, whose other members also include the Chemical Manufacturers Association in the U.S., and the Japanese and Canadian associations.

"I expect that at the next general assembly in 1991, we shall present a new management board and an executive management committee for the entire organization," he predicted. "The new management board will combine both national federations and chemical companies in one body."

CEFIC, whatever its new structure, will be faced with continuing challenges in the environmental field, national and international regulations on such topics as biotechnology, and—with a dramatic flourish last year—the opening of the borders to East bloc nations in Central and Eastern Europe.

According to Metz, "The Western world should be unanimous in supporting the political and economic reform" in the East bloc. "There is a chance to extend the European Community integration process to Central and Eastern Europe. The unification of the two German states will bring the German Democratic Republic into the EC." And the chemical industry "could be a major partner in this process."

Both the Polish and Hungarian national chemical industry associations have expressed a wish to join CEFIC as soon as possible, he said. "For the time being, we have been able to offer them a relationship that involves cooperation and assistance on a variety of matters."

In a subsequent question as to why CEFIC did not accept these two associations immediately, the federation's director general, Hugo Lever, said that "nothing in principle stops us from accepting them. But they have not yet organized themselves so they can join. We need to help them do that, to organize themselves to represent the chemical industry. Within five years, they will be members, is my guess."

CEFIC executives are all keen to work with the chemical industries of the East bloc. However, they are much less so about dealing with the industry of the Mideast, specifically the countries in the Gulf Cooperation Council.

GCC is seeking free-trade agreements with the European Community, particularly for petrochemicals. The Western European petrochemicals industry, under the aegis of the Association of Petrochemicals Producers in Europe (APPE), has lobbied against the notion, and for a while seemed to be winning the arguments. Changes in the top echelons within the EC, however, and some less than subtle political pressures have caused the EC to reconsider.

Said Metz, "I consider the decision by the community to begin negotiations on a future free-trade agreement between the EC and six-nation Gulf Cooperation Council very unfortunate. CEFIC has worked closely with APPE to oppose the idea of such an agreement, ever since it was first proposed in 1984. However, political pressures for such a pact have been applied, and by late last year, both the European Commission and the Council of Ministers altered their stances and decided to open negotiations. I believe that the interests of the Western European petrochemical industry have in fact been sacrificed as a result of this political pressure."

CEFIC has now had two discussion meetings with companies from the GCC countries, one in Granada, Spain, earlier this year, and one in Brussels last week. According to Michael Cockburn, CEFIC's energy expert and representative for APPE, "Our strategy first is to gain time. There is a lot of political pressure, but we do have constructive dialogue developing between us and the companies there in GCC. Although we have been adamant in our resistance to this, it is now on the table, so we are trying, as industrialists, to have discussion with the principal operators in the gulf. We're exchanging views on what

Chemical industry growth is slowing but still healthy

% change from previous year	1988	1989	1990
Gross domestic product	3.3%	3.5%	3.0%
All manufacturing	5.1	4.3	3.0
Chemical industry output	6.7	3.4	2.5
Chemical exports[a]	7.6	5.2	3.5
Chemical imports[a]	9.7	9.9	6.0
Chemical investments	13.0	10.6	8.5
Chemical industry employees	0.7	1.1	0.5

a Includes trade among Western European countries. **Source:** European Chemical Industry Federation (CEFIC)

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the industry can do or expect, in areas, for example, such as plastics waste management."

For CEFIC, the annual meetings have also become a welcome opportunity to focus on contributions the industry is making to the environment, rather than just to bemoan problems with environmentalists, hyperactive legislators, and others. This year, the meeting marked the emergence of the humble 55-gal steel drum as an environmental superstar in the second biennial CEFIC environmental award. The first award was given in 1988 for newly devised technology for restoring historical art treasures. This year's award was far more mundane, but far more practical and of much more significance to the everyday world of the chemical industry.

The award, amounting to approximately $30,000, went to Mauser-Werke GmbH, of Brühl, West Germany, for its "optimally drainable steel drum." Mauser (no connection to the Mauser of armaments fame) introduced the new drum design, which can work on either steel drum or plastic drum or can, in 1989. It features a newly designed top end that helps drain and empty contents out of the drum.

According to Märten Burgdorf, director of Mauser, in traditional designs some 800 to 1200 g of material usually remain in a drum and can't be removed. This then must be dealt with by a drum reconditioner, usually in hazardous waste disposal. The units tend to become a bit interchangeable, but his point is clear: "The target of our research work was to empty the drum, 1 L more. Instead of 1000 g, we wanted to empty it to zero or at least down to 50 g." By Burgdorf's estimates, if the industry could save 1 L for each of the 35 million drums manufactured and the 16 million reconditioned yearly in Western Europe, it would be "a tremendous savings in hazardous wastes."

"Worldwide," he adds, "there are 120 million new drums and 110 million reconditioned drums filled every year. With the new design, 230,000 [cubic meters] of hazardous waste are avoided—an amount of 100 meters length, 100 meters width, and 23 meters height." □

Tight supply of acrylic esters to continue

The supply of acrylic esters is expected to continue to be tight, concludes a recent report by Eldib Engineering & Research Inc., a chemical market research firm located in Berkeley Heights, N.J. Acrylic esters include *n*-butyl acrylate, ethyl acrylate, 2-ethylhexyl acrylate, and methyl acrylate. U.S. supply has been tight for a couple of years, says Paul Gierer of Eldib, because production has not met the growing demands of major end-use markets. Tight supply of acrylic acid feedstock is also a contributing factor.

With the current very high capacity use for acrylic esters, Gierer says, the situation is not expected to improve until capacity additions by the major producers are brought on line in the next year or two. According to SRI International, as of January 1990, producers of acrylic esters are BASF, Union Carbide, Hoechst Celanese, and Rohm & Haas, with a total industry capacity of 1.46 billion lb. Significant expansions noted in the report that are slated to be completed in the next couple of years are 150 million lb per year by Hoechst Celanese at Clear Lake, Tex.; 200 million by Rohm & Haas at Deer Park, Tex.; and at least a 70% increase by Union Carbide at its Taft, La., site.

Although U.S. capacity will reach nearly 2 billion lb per year with the announced expansions, a large percentage of U.S. output goes into captive use or is exported. And, with production levels now below demand, Eldib reports that some suppliers are imposing restrictions on order size or are unable to accept new customers. The current tight supply situation, which will exist at least until the expansions are completed, is making the U.S. market attractive to foreign suppliers.

Ann Thayer

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Administration Documents 20 Years Of Environmental Improvement

Economy grew 70% and population 22%, but most major air quality pollutants, including carbon monoxide, lead, and SO_2 were slashed

David J. Hanson, C&EN Washington

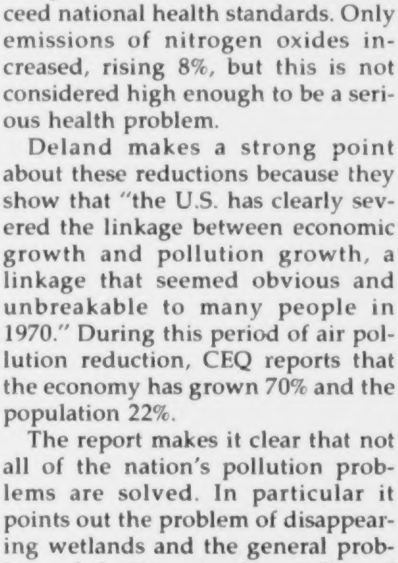
The President's Council on Environmental Quality has released its 20th annual report on the condition of the nation's air, land, and water. Departing from the more statistical treatments of this information in the past, this report tries to look at overall gains during that period. The general conclusion is that the problems addressed in the past 20 years have been substantially dealt with, but new pollution issues are proving more difficult to resolve.

"This report is a 20-year perspective on the U.S. environment," says CEQ chairman Michael R. Deland. "The results are heartening. The American public can take comfort and pride in the progress it has made." The CEQ report itself is a sign of some progress. As the first environmental office set up under the 1970 National Environmental Policy Act, CEQ had lost most of its staff and functions during the Reagan Administration. Deland has helped revitalize the council, doubling its staff to about 20 and planning on doubling it again in the next year.

The CEQ report makes much of the progress made in many areas of environmental cleanup. It points out that in the area of air pollution, most major air quality pollutants have been significantly reduced. Annual emissions of lead are down 96% from 20 years ago, particulate emissions 61%, and sulfur dioxide emissions 28% since 1970. For carbon monoxide, total emissions have fallen 38%, but despite this progress many urban areas in the U.S. still exceed national health standards. Only emissions of nitrogen oxides increased, rising 8%, but this is not considered high enough to be a serious health problem.

Deland makes a strong point about these reductions because they show that "the U.S. has clearly severed the linkage between economic growth and pollution growth, a linkage that seemed obvious and unbreakable to many people in 1970." During this period of air pollution reduction, CEQ reports that the economy has grown 70% and the population 22%.

The report makes it clear that not all of the nation's pollution problems are solved. In particular it points out the problem of disappearing wetlands and the general problem of declines in the quality of coastal waters and estuaries in the past two decades. Some of this is attributed to population growth along coastlines, which leads to more runoff and the filling in of wetlands. Increasing agriculture is also seen as a major contributor to wetlands loss.


Deland: the results are heartening

Considering the environmental progress in general, the report observes that the U.S. has been successful in improving environmental quality when the existence of a problem has been widely recognized and the sources of the problem well defined. This fits with the improved air pollution data. But in cases where general recognition of a problem emerged slowly over time, as in the case of acid rain or chlorofluorocarbon contamination, or in cases where the sources of a problem are diverse, environmental progress has been slow and painful.

A major chapter in the report deals with the broad issue of pollution prevention. In addition to discussing the role industry plays here, the report includes energy efficiency, agricultural practices, and consumer lifestyles as part of this issue. Economics is given credit for starting the shift from so-called end-of-pipe controls to finding ways to reduce the amount of waste generated to begin with. The CEQ report cited 3M as a pioneer in the field for beginning its "Pollution Prevention Pays" program in 1975. Since then, incentives for companies to reduce levels of waste have increased tremendously, making it financially sound to explore pollution prevention. Passage of new regulations, such as the Section 313 requirements under the 1986 Superfund reauthorization that force companies to report annual releases of toxic chemicals, are cited as adding pressure to companies to cut pollution.

CEQ mentions a few challenges

ahead for pollution prevention. One of the most critical is that many smaller businesses do not have access to the technical information on profitable pollution prevention strategies that are developed by the larger corporations. Because of the highly competitive nature of business, CEQ recognizes that sharing information is not straightforward. CEQ hopes that programs devised by state agencies and the Environmental Protection Agency will facilitate this technology transfer without jeopardizing proprietary data. Strong corporate leadership is also needed to overcome industry's inherent resistance to change.

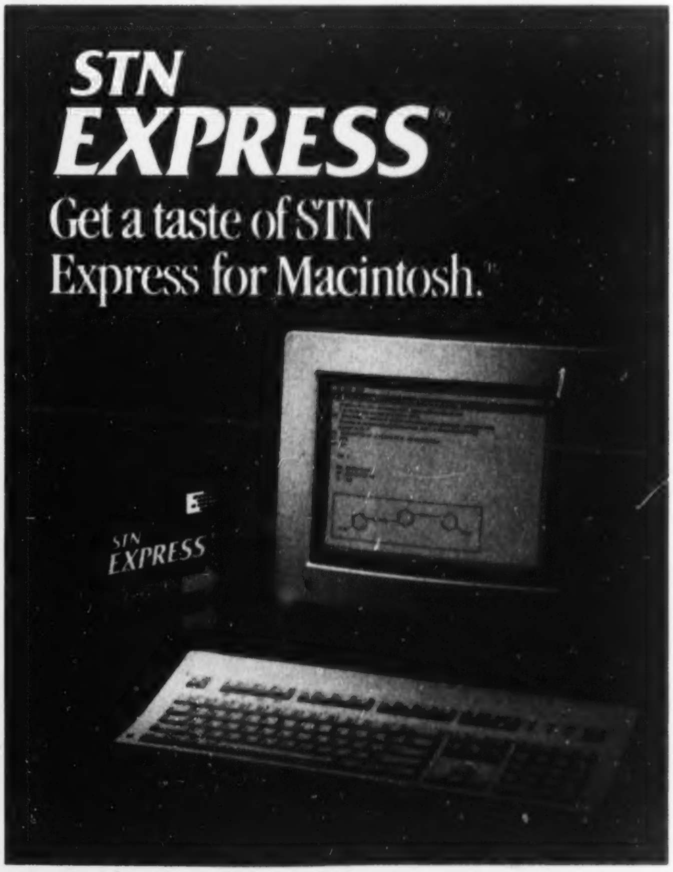
Pollution abatement costs chemical industry billions yearly

	Capital expenditures			Operating costs			
$ Millions	Air	Water	Solid waste	Air	Water	Solid waste	Total
1973	$164.4	$214.6	$ 16.8	$174.1	$ 247.6	$ 80.2	$ 897.7
1974	250.6	264.4	24.1	203.8	335.6	104.0	1182.5
1975	359.5	387.7	35.0	249.9	430.9	126.7	1589.7
1976	319.8	577.4	44.7	295.6	514.7	173.2	1925.4
1977	339.9	593.1	49.6	335.5	685.2	217.6	2220.9
1978	376.3	385.9	65.1	398.8	794.1	280.1	2300.3
1979	314.6	360.7	95.6	485.3	895.2	287.0	2438.4
1980	325.9	350.0	104.8	539.9	942.9	368.8	2632.3
1981	335.0	322.2	95.6	571.7	1069.1	406.9	2800.5
1982	272.8	256.5	98.3	556.1	1112.3	438.2	2734.2
1983	159.0	187.4	49.0	624.9	1106.0	467.4	2593.7
1984	142.9	212.4	32.7	622.0	1206.3	517.1	2733.4
1985	193.7	271.5	272.5	672.9	1267.7	599.4	3223.7
1986	197.8	325.5	101.0	646.5	1301.8	705.9	3278.5

Source: Council on Environmental Quality

International issues occupy a major portion of the report and it goes into some detail on the various programs in which the U.S. is involved. Although it reviews the major international issues, such as acid rain and global warming, it makes no judgments about the U.S. position on these issues or how it might be at odds with other nations' views. Other international problems CEQ discusses include transboundary movement of hazardous waste, biodiversity of species and habitats, and threats to the world's oceans. The report includes extensive lists of U.S. meetings on these and other issues and bilateral and multilateral environmental agreements into which the U.S. has entered.

In keeping with the very different nature of this CEQ report, there is a chapter devoted to the impact science and technology has had on environmental policies. This is the first



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time CEQ had given so much attention to technology, even though it has been the technology developments of the past 20 years that have fueled many of the environmental issues of today.

The development of advanced gas chromatography-mass spectrometry systems is highlighted as the leading reason for progress in many areas. By moving detection limits from the parts-per-thousand range to the parts-per-trillion range and lower, many pollutants that once went undetected are now routinely measured. And over the years, a library of "fingerprints" for chemical identification can use computers to match contaminating chemicals with the producers. Other technological advancements cited include atomic absorption spectroscopy, and inductively coupled plasma spectrometers.

Advanced instrumentation now routinely measures pollutants that once went undetected

Research and development isn't ignored either. The trend CEQ emphasizes is toward partnerships among private, academic, and government sectors. Twenty years ago there was little interplay among these institutions to deal with environmental problems. Now many organizations are supporting research to solve these issues. The Superfund Innovative Technology Evaluation program is mentioned as an example of how the government is helping the private sector develop better technology for waste site cleanups. However, though other programs are mentioned, CEQ doesn't go into the amount of effort industry has had to invest over the past 20 years to meet federal pollution requirements.

As a retrospective analysis, the report dwells mostly on the past and does not spend much time on the issues that have only recently become serious concerns. The current policies on issues such as global warming and chlorofluorocarbon depletion of stratospheric ozone are pretty much left to future volumes. There are extensive chapters included on improvements in enforcement of environmental regulations and on the history of contamination problems in the Great Lakes.

Tom Super, who was the overall manager of the report, says CEQ tried to stay as apolitical in preparing this report as it could, but still the overall view is one of substantial progress. "In a pluralistic society, incremental progress toward long-term goals is what we should strive for. And this incremental progress will be fraught with political strife and energy. We took a look at the cumulation of these incremental changes over the past 20 years and found all areas positive," Super explains. □

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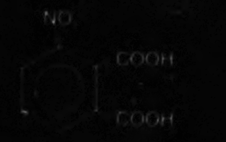
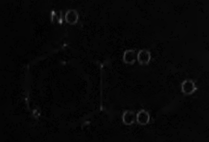


3 - Nitrophthalic acid



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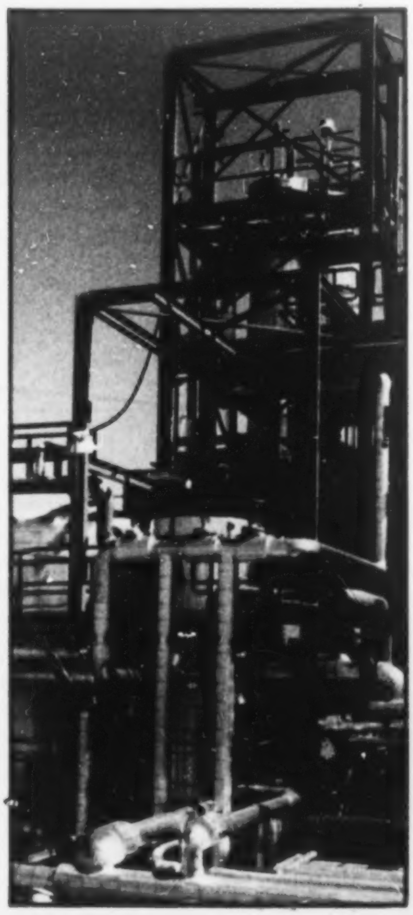
CIRCLE 31 ON READER SERVICE CARD

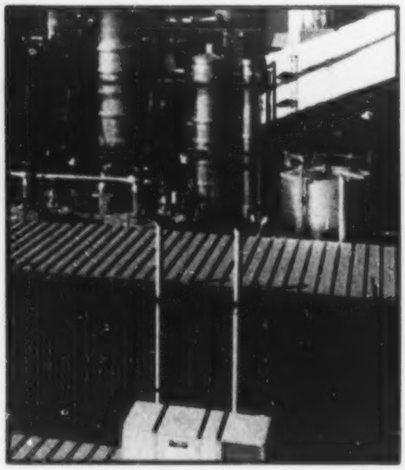
Facts & Figures

at a glance



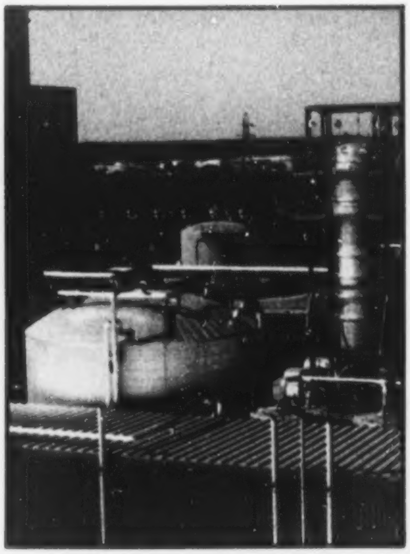
Section One: Production

Output of chemicals continued to expand in the U.S. last year, but the increase was slower than in any of the three previous years. And for the big-volume commodity chemicals that are the core of the industry, the record was spotty. Ethylene production, for example, was down 6% from the year before and styrene nearly 10%. Plastics, which in recent years had set the growth pace for the industry, also were hit by a poor year, with polyethylene particularly lackluster. For synthetic fibers, the year was flat. **Page 36**



Section Two: Finances

The surge in profits enjoyed by U.S. chemical firms since 1986 stalled in 1989. Profitability fell sharply, in fact, for several of the biggest producers of basic chemicals. Even so, for the industry as a whole, net income remained high in comparison with any year prior to 1988. The industry also continued to spend more heavily for new plants, although 1989's increase was far less than 1988's. R&D budgets also rose more moderately. **Page 45**



Section Three: Employment

The number of people working in the chemical industry increased somewhat less than 3% last year, reaching a level close to its high of about a decade ago. Growth has been strongest in such areas as drugs and toiletries. Productivity improved, but not nearly so much as in recent years. **Page 60**

for the chemical industry

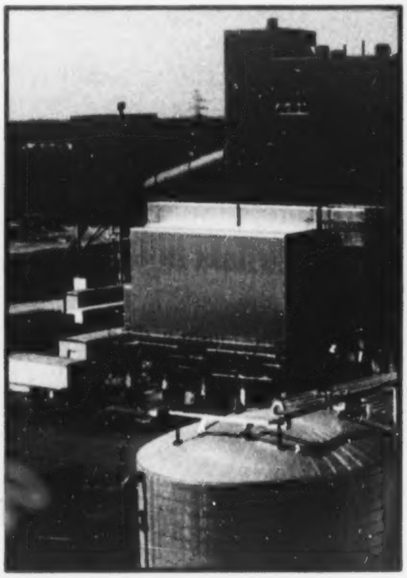
Last year was a good one for the chemical industry, but as the data tabulated and graphed on the following pages of C&EN's annual Facts & Figures issue demonstrate, it was hardly one to cheer about.

The U.S. increased its output of chemical products. The gain of 3% was well below that of the previous three years, however, as demand in many of the major markets for chemicals weakened appreciably after being relatively strong when the year began. As a result, most of the growth in chemical production was chalked up early on; at year's end output was running about at the same level as when it began.

At the same time, production capacity had been built up rapidly in the past year or so. As a result, although prices for chemicals were up on average for the year as a whole, with competitive pressures building, they weakened considerably for many products as the year wore on. One glaring consequence was a decided drop in chemical companies' earnings during 1989's second half.

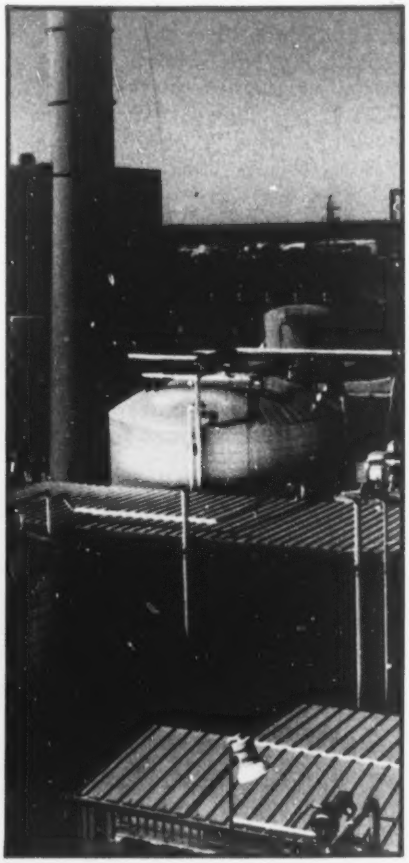
Section Four: Markets

Although continued growth in spending on the part of U.S. consumers kept demand for chemical products high in 1989, some major markets weakened. Home building was down for the third year as housing starts fell to the fewest since 1982. Motor vehicle assemblies also slipped. **Page 64**



Section Five: Foreign Trade

With U.S. companies boosting their exports a healthy 13% last year to capture a bigger share of the growing world market for chemicals, the trade surplus in chemicals widened further to almost $16 billion. Only West Germany surpassed the U.S. as a chemical exporter. **Page 66**



Section Six: Foreign Chemical Industries

Business continued favorable for chemical industries throughout the industrialized world in 1989. In Western Europe, profits remained high even though output dipped for many chemicals. In Japan, earnings were strong, as well. But in Canada, lower demand and prices cut into income. And in East Europe, output deteriorated. **Page 70**

Growth slackens appreciably as 1980s end

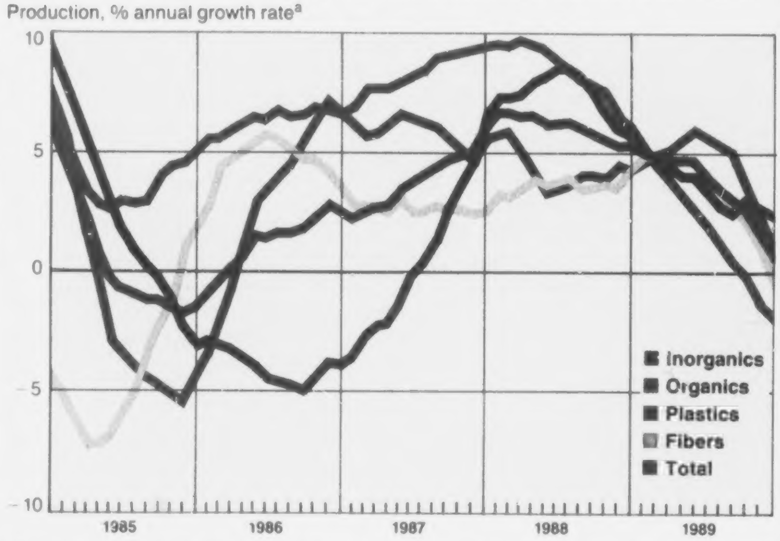
Production by the U.S. chemical industry was showing signs of softness as it ended the decade of the 1980s. The strong and steady growth that characterized most of the second half of the 1980s was slackening appreciably by decade's end. Although overall output for chemicals posted a 3% gain in 1989 over 1988 levels, the rise was considerably less than its average annual increase of 5% in the three previous years. The slowdown was more dramatic for the largest-volume chemicals, C&EN's Top 50, which posted only a 0.2% gain in 1989 production, compared with 7% growth in 1988. By the end of 1989, production growth rates were much lower for all major sectors of the chemical industry.

Most of the big drops in production came in the organic chemicals sector. Output of the largest-volume organic chemicals as a group declined more than 3% in 1989, led by a 6% drop for ethylene, 5% for propylene, 12% for methanol, 8% for toluene, and a whopping 19% for terephthalic acid. By contrast, ethylene dichloride, carbon dioxide, and vinyl chloride all posted output gains in 1989, rising 5%, 7%, and 6%, respectively.

Production within the inorganics segment of the largest-volume chemicals rose overall 2%, thanks to solid, if unspectacular growth in the biggest-volume products in this class, such as sulfuric acid, nitrogen, and lime, each up 3%; oxygen, up 1%; and sodium hydroxide, up 5%.

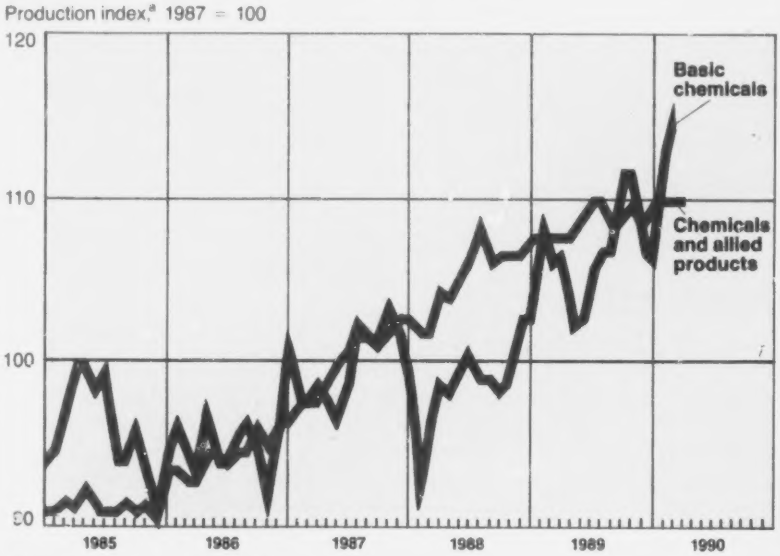
Synthetic fibers showed no net change in 1989. Fertilizer consumption was also unchanged in the year that ended last June, compared with 2% growth in each group in 1988. Synthetic rubber output grew only 1% last year, down from a 7% gain the year before. Of all market sectors, only pesticides showed major growth in output in 1989, increasing 12% over the previous year.

Growth slowed markedly for all chemical sectors in 1989



a Average running annual growth rates in production of major plastics, inorganic and organic chemicals, and all chemicals, and in shipments of man-made fibers. **Sources:** International Trade Commission, Bureau of the Census, Society of the Plastics Industry, Textile Economics Bureau

Chemical production overall leveled off



a Seasonally adjusted. **Source:** Federal Reserve Board

TOP 50 CHEMICALS: Overall production has changed little since 1979

Rank			Billions of lb		Common units[b]		Average annual growth			
1989	1988[a]		1989	1988	1989	1988	1988–89	1987–88	1984–89	1979–89
1	1	**Sulfuric acid**	86.80	84.28	43,399 tt	42,141 tt	3.0%	7.3%	0.8%	0%
2	2	**Nitrogen**	53.77	52.32	742 bcf	722 bcf	2.8	10.4	2.3	5.7
3	3	**Oxygen**	37.75	37.42	456 bcf	452 bcf	0.9	15.9	3.4	0
4	4	**Ethylene**	34.95	37.20	34,953 mp	37,203 mp	−6.0	6.3	2.2	1.6
5	5	**Ammonia**	33.76	33.64	16,878 tt	16,821 tt	0.3	4.1	0.2	−1.0
6	6	**Lime**[c]	32.99	32.02	16,495 tt	16,011 tt	3.0	5.5	0.6	−2.4
7	7	**Phosphoric acid**	23.12	23.35	11,559 tt	11,677 tt	−1.0	11.5	0.3	1.1
8	8	**Chlorine**	22.32	22.51	11,161 tt	11,257 tt	−0.9	2.5	0.8	−0.9
9	10	**Sodium hydroxide**	22.15	21.05	11,075 tt	10,527 tt	5.2	−8.6	0.3	−1.4
10	9	**Propylene**	20.23	21.22	20,229 mp	21,224 mp	−4.7	14.6	5.4	3.6
11	11	**Sodium carbonate**[d]	19.79	19.26	9,896 tt	9,632 tt	2.7	8.3	3.1	1.8
12	12	**Nitric acid**	15.98	15.98	7,991 tt	7,991 tt	0	12.5	0.7	−1.1
13	13	**Urea**[e]	15.47	15.83	7,733 tt	7,914 tt	−2.3	6.4	0.8	1.0
14	14	**Ammonium nitrate**[f]	15.11	15.01	7,557 tt	7,504 tt	0.7	17.0	1.1	−0.9
15	15	**Ethylene dichloride**	13.68	13.03	13,675 mp	13,028 mp	5.0	−5.6	5.0	1.5
16	16	**Benzene**	11.67	11.73	1,585 mg	1,593 mg	−0.5	0.5	3.8	−0.5
17	18	**Carbon dioxide**[g]	10.83	10.12	5,413 tt	5,058 tt	7.0	2.6	3.5	6.1
18	20	**Vinyl chloride**	9.62	9.06	9,618 mp	9,058 mp	6.2	10.1	9.6	4.2
19	19	**Ethylbenzene**	9.22	9.93	9,223 mp	9,929 mp	−7.1	5.5	4.1	0.9
20	17	**Terephthalic acid**[h]	8.31	10.23	8,309 mp	10,234 mp	−18.8	26.2	7.0	3.0
21	21	**Styrene**	8.13	8.98	8,129 mp	8,984 mp	−9.5	11.1	1.1	0.8
22	22	**Methanol**	7.14	8.14	7,139 mp	8,142 mp	−12.3	11.7	−2.7	−0.3
23	24	**Formaldehyde**[i]	6.37	6.28	6,370 mp	6,280 mp	1.4	3.3	1.8	0.6
24	23	**Toluene**[j]	5.84	6.35	805 mg	875 mg	−8.0	−5.7	2.0	−2.2
25	29	**Xylene**	5.80	5.48	805 mg	761 mg	5.8	−4.3	−1.2	−1.9
26	28	**Ethylene glycol**	5.50	5.52	5,499 mp	5,517 mp	−0.3	22.2	2.7	1.5
27	27	***p*-Xylene**	5.49	5.60	5,494 mp	5,601 mp	−1.9	8.7	5.2	1.7
28	25	**Ethylene oxide**	5.32	5.95	5,322 mp	5,953 mp	−10.6	5.9	−1.4	−0.8
29	30	**Hydrochloric acid**	5.26	5.28	2,628 tt	2,640 tt	−0.5	−11.9	−0.5	−1.6
30	26	**Methyl *tert*-butyl ether**[k]	4.98	5.68	4,976 mp	5,680 mp	−12.4	68.4	29.3	na
31	31	**Ammonium sulfate**	4.71	4.67	2,354 tt	2,333 tt	0.9	6.9	2.6	0
32	32	**Cumene**	4.54	4.46	4,535 mp	4,455 mp	1.8	7.3	3.9	1.5
33	33	**Phenol**[l]	3.89	3.56	3,893 mp	3,562 mp	9.3	9.9	6.1	2.7
34	36	**Acetic acid**	3.83	3.16	3,826 mp	3,159 mp	21.1	−2.1	7.9	1.6
35	34	**Potash**[m]	3.35	3.35	1,521 tmt	1,521 tmt	0	20.5	−0.6	−3.7
36	37	**Propylene oxide**	3.20	3.11	3,200 mp	3,110 mp	2.9	19.2	12.5	3.6
37	35	**Butadiene**[n]	3.09	3.17	3,094 mp	3,169 mp	−2.4	5.6	4.8	−1.5
38	38	**Carbon black**	2.91	2.92	2,913 mp	2,916 mp	−0.1	7.0	0.1	−1.3
39	39	**Acrylonitrile**	2.61	2.61	2,608 mp	2,609 mp	0	2.3	3.3	2.6
40	42	**Acetone**	2.50	2.30	2,497 mp	2,303 mp	8.4	10.6	6.0	−0.6
41	40	**Vinyl acetate**	2.47	2.56	2,470 mp	2,561 mp	−3.6	2.2	4.1	2.2
42	42	**Cyclohexane**	2.39	2.30	2,389 mp	2,297 mp	4.0	2.1	3.7	−0.1
43	41	**Aluminum sulfate**	2.35	2.46	1,173 tt	1,232 tt	−4.8	0.7	0.8	−1.1
44	44	**Titanium dioxide**	2.22	2.04	1,110 tt	1,022 tt	8.6	7.4	5.9	4.1
45	48	**Calcium chloride**[o]	1.92	1.46	960 tt	729 tt	31.7	−5.7	−1.8	−0.2
46	46	**Sodium silicate**	1.75	1.62	877 tt	812 tt	8.0	−14.7	5.1	0.8
47	47	**Adipic acid**	1.64	1.60	1,640 mp	1,600 mp	2.5	1.8	3.4	−0.6
48	45	**Sodium sulfate**[p]	1.60	1.63	800 tt	817 tt	−2.1	1.5	−1.7	−3.3
49	49	**Isopropyl alcohol**	1.43	1.39	1,432 mp	1,389 mp	3.1	5.8	0.5	−2.8
50	50	**Caprolactam**	1.31	1.26	1,312 mp	1,261 mp	4.0	8.6	5.0	3.3
TOTAL ORGANICS			210.61	217.69			−3.3%	7.8%	3.6%	1.4%
TOTAL INORGANICS			400.44	392.41			2.0%	7.0%	1.3%	0.2%
GRAND TOTAL			611.04	610.11			0.2%	7.3%	2.0%	0.6%

[a] Revised. [b] tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. [c] Except refractory dolomite. [d] Natural and synthetic. [e] 100% basis. [f] Original solution. [g] Liquid and solid only. [h] Includes both acid and ester without double counting. [i] 37% by weight. [j] All grades. [k] Production data for earlier years unavailable. [l] Synthetic only. [m] K_2O basis. [n] Rubber grade. [o] Solid and liquid. [p] High and low purity. na = not available.

PRODUCTION: 1989 was a strong year for basic chemicals, a poor one for synthetics

Industrial production indexes, 1987 = 100	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
Total index	108.1	105.4	100.0	95.3	94.4	92.8	84.9	81.9	85.7	84.1	85.7	3%	2%
Manufacturing, total	108.9	105.8	100.0	94.3	91.6	89.3	80.9	76.6	80.3	78.8	80.9	3	3
Nondurable manufacturing	106.4	103.6	100.0	94.9	91.5	90.8	87.0	82.5	84.5	83.1	84.6	3	2
Chemicals and products	108.5	105.4	100.0	94.6	91.4	91.4	87.5	81.8	89.2	87.8	91.3	3	2
Chemicals and synthetic materials	106.5	102.5	100.0	93.9	92.2	92.8	88.6	79.4	91.2	86.3	96.6	4	1
Basic chemicals	106.6	98.3	100.0	95.1	96.1	96.9	92.1	86.5	96.9	96.5	101.8	8	0
Alkalies and chlorine	103.2	96.0	100.0	92.1	93.6	95.3	87.9	82.1	94.6	101.5	110.7	8	−1
Industrial gases	108.0	104.1	100.0	98.8	92.8	97.5	85.9	80.1	91.2	91.5	93.3	4	1
Inorganic pigments	111.0	102.6	100.0	96.2	95.1	89.0	87.3	79.1	90.7	90.6	93.3	8	2
Inorganic chemicals, nec	105.7	96.4	100.0	94.7	97.2	98.0	94.3	89.2	98.7	96.8	102.4	10	0
Industrial organic chemicals	109.2	103.1	100.0	95.1	94.1	93.4	89.9	81.0	97.0	92.8	101.8	6	1
Synthetic materials	103.1	104.4	100.0	91.6	86.9	88.9	84.3	71.8	79.5	71.2	85.8	−1	2
Plastics materials	106.7	106.8	100.0	88.2	84.1	81.1	74.4	64.4	68.3	64.2	70.4	0	4
Synthetic rubber	92.4	105.0	100.0	109.3	114.4	132.8	124.1	110.5	114.5	110.8	130.0	−12	−3
Man-made fibers	98.7	99.5	100.0	93.7	86.6	93.3	92.3	76.4	91.7	74.9	104.6	−1	−1
Chemical products	110.1	107.5	100.0	95.9	90.2	89.0	86.6	83.0	85.4	87.6	85.8	2	3
Drugs and medicines	108.1	107.2	100.0	96.7	88.5	86.9	86.1	82.7	80.9	80.2	77.1	1	3
Soaps and toiletries	111.1	107.9	100.0	96.7	91.3	90.6	91.4	89.2	97.7	103.5	97.9	3	1
Paints	104.8	103.9	100.0	97.5	95.7	91.8	84.6	78.8	84.1	87.0	92.2	1	1
Agricultural chemicals	108.2	107.2	100.0	88.5	96.1	102.0	87.5	88.8	102.3	97.2	93.7	1	1
Petroleum products	106.1	103.4	100.0	98.9	92.6	92.8	89.6	89.3	94.1	99.0	107.2	3	0
Rubber and plastics products	108.9	105.9	100.0	90.8	85.8	83.8	74.3	65.9	66.6	61.7	67.9	3	5

nec = not elsewhere classified. **Source:** Federal Reserve Board

MINERALS: Production increased for most chemical minerals last year

Thousands of tons	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
Bromine, sold or used[a]	190[b]	180	168	155	160	193	185	200	189	189	249	6%	−3%
Calcium chloride, production[c,d]	962[b]	731	658	780	940	1,036	912	853	917	811	981	32	3
Lime, sold or used[e]	17,079[b]	16,658	15,733	14,474	15,690	15,922	14,867	14,075	18,890	19,037	20,983	3	−2
Lithium, consumption[d,f]	3.2[b]	3.0	2.7	2.6	2.5	3.2	2.2	2.0	3.2	3.0	3.2	7	0
Phosphate rock													
Marketable production	53,900	50,000	45,145	44,445	56,035	54,230	46,928	41,241	59,110	59,982	56,891	8	−1
Exports	9,036	8,920	9,319	8,651	10,071	12,707	13,239	10,849	11,458	15,737	15,827	1	−4
Potash (K_2O equivalent)[g]													
Production	1,700[b]	1,677	1,391	1,325	1,429	1,724	1,575	1,967	2,377	2,468	2,453	1	−4
Imports[j]	4,740[b]	4,648	4,490	4,643	5,063	5,323	4,894	4,253	5,287	5,481	5,693	2	−2
Apparent consumption	6,020[b]	5,803	5,609	5,338	5,893	6,638	6,231	5,647	6,849	6,999	7,626	4	−2
Salt, production[h]	38,466[d]	39,170	36,943	37,282	39,217	39,181	32,973	37,665	38,899	40,396	45,820	−2	nc
Evaporated[i]	6,851[d]	7,203	6,896	6,316	6,162	6,334	5,276	5,273	6,206	6,358	6,248	−5	nc
Rock[i]	13,945[d]	12,750	12,230	13,333	13,990	13,653	11,870	12,806	11,866	11,806	14,891	9	nc
Salt in brine[i]	17,671[d]	19,218	17,817	17,633	19,065	19,195	15,827	19,586	20,826	22,231	24,681	−8	nc
Sodium carbonate, production[j]	9,775[b]	9,632	8,891	8,438	8,511	8,511	8,467	7,819	8,281	8,275	8,253	1	2
Sulfur, production[k]	12,778	11,845	11,616	12,221	12,797	11,742	10,240	10,788	13,388	13,080	13,339	8	0
Apparent consumption[l]	13,983	14,012	12,481	11,669	13,192	13,976	12,112	11,088	14,093	15,056	15,145	0	−1
Frasch, production	4,286	3,499	3,530	4,457	5,524	4,622	3,530	4,641	6,997	7,044	7,007	22	−5
Recovered elemental, production	7,176	7,103	6,791	6,411	5,857	5,747	5,462	4,855	4,695	4,490	4,486	1	5
Other, production	1,316	1,243	1,296	1,354	1,416	1,372	1,249	1,293	1,695	1,547	1,845	6	−3

a Elemental bromine sold as such or used in preparation of bromine compounds by primary producers. **b** Preliminary. **c** 75% $CaCl_2$ equivalent. **d** Estimated. **e** Includes Puerto Rican production. **f** Lithium content basis. **g** Includes muriate and sulfate of potash, potassium magnesium sulfate, and parent salts; excludes other chemical compounds containing potassium. **h** Figures for 1979–80 are total obtained by all recovery methods that was sold or used by domestic producers (slightly different from U.S. production); figures for 1979–81 include Puerto Rican production. **i** Sold or used as such. **j** Natural and synthetic for 1979–86, natural only in 1987–89. **k** Sulfur content basis. **l** Calculated from shipments plus imports minus exports (sulfur content basis). **nc** = not comparable. **Source:** Bureau of Mines

1 Production by the U.S. Chemical Industry

ORGANIC CHEMICALS: Mixed results show 1989 production down more often than up

Millions of lb unless otherwise noted	Production 1989[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	1979–89
Acetic acid, synthetic	3,826	3,159	3,246	2,728	2,897	2,619	2,807	2,748	2,705	2,977	3,265	21%	2%
Acetone	2,497	2,303	1,846	1,910	1,788	1,862	1,859	1,694	2,144	2,076	2,653	8	−1
Acrylonitrile	2,619	2,609	2,452	2,182	2,349	2,219	2,146	2,035	1,997	1,830	2,018	0	3
Aniline	1,025	1,029	829	824	716	786	663	557	634	659	690	0	4
Benzene, mg[b,c]	1,585	1,608	1,575	1,362	1,283	1,318	1,232	1,052	1,308	1,534	1,612	−1	0
Bisphenol A	1,136	1,340	1,000	956	949	762	643	480	555	530	576	−15	7
1,3-Butadiene[d]	3,094	3,169	2,931	2,546	2,340	2,452	2,353	1,915	2,986	2,799	3,583	−2	−1
1-Butanol	1,049	1,194[a]	1,155	881	716	908	833	730	809	790	766	−12	3
Caprolactam	1,312	1,261	1,156	1,109	1,089	1,027	977	793	928	905[a]	945	4	3
Carbon tetrachloride	na	761	672	627	646	713	573	587	726	710	714	na	na
Chloroform	580	524	462	422	275	405	362	299	405	273	356	11	5
Cumene	4,534	4,455	4,105	3,745	2,627	3,754	3,345	2,743	3,309	3,459	3,917	2	1
Cyclohexane	2,388	2,297	2,276	2,070	1,657	1,994	1,656	1,275	1,820	1,964	2,425	4	0
Dioctyl phthalate	292	344	343	296	275	301	300	266	304	353	336	−15	−1
Ethanol, synthetic	na	562	574	529	649	1,060	1,077	1,023	1,317	1,451	1,408	na	na
Ethanolamines[e]	632	608	627	543	537	504	468	416	429	376	420	4	4
Ethylbenzene	9,221	9,929	9,346	9,020	7,386	7,562	7,876	6,656	7,813	7,642	8,448	−7	1
Ethyl chloride	na	152	155	164	171	290	282	339	324	396	582	na	na
Ethylene	34,947	37,204	34,951	32,859	29,847	31,383	28,680	24,501	29,418	28,667	29,904	−6	2
Ethylene dichloride	13,673	13,028	12,197	12,940	12,101	10,710	11,506	7,619	9,974	11,108	11,794	5	1
Ethylene glycol	5,498	5,517	5,183	4,771	4,178	4,823	4,425	4,309	4,143	4,386	4,729	0	2
Ethylene oxide	5,321	5,953	4,785	5,430	5,430	5,699	5,534	4,987	4,937	5,220	5,665	−11	−1
2-Ethylhexanol	797	743	662	571	536	541	387	325	389	367	318	7	10
Formaldehyde, 37%[f]	6,369	6,280	5,733	5,549	5,606	5,815	5,465	4,817	5,721	5,555	5,971	1	1
Isobutylene	1,164	1,244	1,035	1,124	na	883	760	741	1,035	1,052	na	−6	na
Isopropyl alcohol	1,432	1,389	1,371	1,301	1,235	1,394	1,209	1,380	1,669	1,836	1,900	3	−3
Maleic anhydride	425	448	382	359	394	359	299	260	293	304	323	−5	3
Methanol, synthetic	7,138	8,142	7,537	7,205	5,003	8,186	7,982	7,555	8,577	7,153	7,367	−12	0
Methyl chloride	414	597	373	605	410	482	409	366	405	362	463	−31	−1
Methyl ethyl ketone	428	482	672	600	537	543	531	468	614	692	716	−11	−5
Methyl methacrylate	1,162	1,100	1,029	943	858	917	844	721	592	564	633	6	6
Methylchloroform	778	724	694	652	869	675	586	595	611	587	656	7	2
Methylene chloride	470	504	516	566	467	607	584	532	891	780	931	−7	−7
Perchloroethylene	475	498	473	414	678	573	547	585	691	765	773	−5	−5
Phenol, synthetic[g]	3,892	3,562	3,351	3,115	2,841	2,889	2,638	2,023	2,578	2,568	2,981	9	3
Phthalic anhydride	1,101	999	1,035	863	820	870	838	684	870	818	1,013	10	1
Propylene[h]	20,225	21,224	19,019	16,522	14,887	15,559	13,959	12,535	13,482	13,676	14,198	−5	4
Propylene glycol	843	840	747	573	500	462	484	400	473	488	610	0	3
Styrene, monomer	8,128	8,984	8,014	7,888	7,622	7,709	6,802	5,942	6,679	6,856	7,484	−10	1
Terephthalic acid, dimethyl ester[i]	8,308	10,234	7,601	6,257	6,490	5,912	5,626	4,843	6,235	6,054	6,159	−19	3
Toluene, mg[b,j]	805	892	967	611	698	728	780	714	852	1,010	1,001	−10	−2
Vinyl acetate	2,469	2,561	1,813	1,710	2,112	2,024	1,963	1,876	1,936	1,922	1,982	−4	2
Vinyl chloride	9,617	9,058	8,402	8,439	9,463	6,084	6,875	4,902	6,874	6,466	6,389	6	4
***o*-Xylene**	842	971	940	788	675	688	781	802	918	995	1,082	−13	−2
***p*-Xylene**	5,493	5,601	5,155	5,035	4,779	4,264	4,114	3,391	4,532	4,238	4,650	−2	2

Note: mg = millions of gallons. a Preliminary. b Tar distillers and coke-oven operators not included. c Specification grades. d Rubber grade. e Mono-, di-, and triethanolamines. f By weight. g Does not include data for coke ovens and gas-retort ovens. h All grades. i Includes both acid and dimethyl ester (DMT), without double counting. j High-purity toluene, includes material used in blending motor fuel. na = not available. **Source:** International Trade Commission

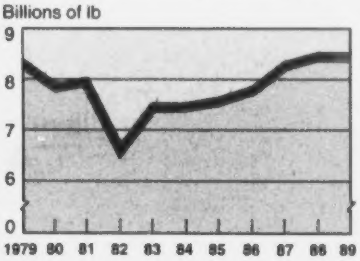
INORGANICS: **Most of the best gains last year were for smaller volume products**

Thousands of tons unless otherwise noted	Production											Annual change	
	1989[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
Aluminum sulfate[b]	1,174	1,232	1,227	1,222	1,268	1,129	1,119	1,154	1,294	1,286	1,315	−5%	−1%
Ammonia, 100%[c,d]	16,825	16,821	16,098	14,474	17,319	16,692	14,072	15,801	19,044	19,653	18,634	0	−1
Ammonium nitrate, 100%[e]	7,966	7,504	6,547	6,089	6,776	7,146	6,240	7,091	8,861	9,128	8,293	6	0
Ammonium sulfate, 100%[d,f]	2,354	2,333	2,189	2,080	2,093	2,067	1,956	1,768	2,185	2,136	2,363	1	0
Chlorine gas[g]	11,092	11,257	11,078	10,436	10,402	10,700	9,960	9,176	10,763	11,421	12,291	−1	−1
Hydrochloric acid, 100%[h]	2,681	2,640	2,996	2,413	2,807	2,732	2,468	2,450	2,574	2,888	3,090	2	−1
Hydrogen, bcf, 100%[i,j]	167	177	173	136	121	109	103	88	105	107	106	−6	5
Hydrogen peroxide, 100%[k]	193	177	153	152	144	139	117	108	111	116	114	9	5
Nitric acid, 100%[k]	8,016	7,991	7,225	6,734	7,631	7,726	6,768	7,390	9,093	9,231	8,916	0	−1
Nitrogen gas, bcf, 100%[i,l]	742	722	685	677	665	661	560	483	490	479	427	3	6
Oxygen, bcf, 100%[i,l]	456	452	405	383	393	375	346	349	431	431	456	1	0
Phosphoric acid, 100% P_2O_5	11,566	11,677	10,619	9,578	10,518	11,370	9,767	8,253	9,958	10,848	10,318	−1	1
Phosphorus[m]	365	343	344	364	359	386	366	361	426	432	460	6	−2
Sodium chlorate, 100%	283	267	289	267	259	295	323	291	297	312	269	6	1
Sodium hydroxide, 100%	11,084	10,527	11,553	10,691	10,811	10,914	10,039	9,385	10,621	11,625	12,759	5	−1
Sodium phosphate[n]	580[o]	549	586	617	625	675	669	651	696	727	757	6	−3
Sodium silicate[p]	873	812	952	791	692	685	710	664	771	805	813	8	1
Sodium sulfate, 100%[q]	799	817	799	837	1,203	901	914	864	1,111	1,140	1,121	−2	−3
Sulfuric acid, 100%[r]	43,410	42,141	39,256	35,759	39,651	41,802	36,583	33,233	40,742	44,158	43,204	3	0
Titanium dioxide, 100%[s]	1,109	1,022	968	931	860	835	760	660	761	727	742	9	4
Urea	7,753	7,914	7,433	6,264	6,678	7,433	6,137	6,470	8,062	7,830	7,000	−2	1

Note: bcf = billions of cubic feet. a Preliminary. b Commercial, 17% Al_2O_3; includes municipalities. c Synthetic anhydrous. d Excludes by-product ammonia liquor and ammonium sulfate. e Original solution. f Synthetic and noncoke by-product. g Includes quantities liquefied for use, storage, or shipment. h Includes anhydrous hydrochloric acid production. i High- and low-purity gas. j Liquid and gas; excludes amounts vented and used as fuel, and amounts produced in petroleum refineries for captive use. k Includes unspecified amounts produced but not withdrawn from the system. l Excludes amounts produced and consumed in making synthetic ammonia or ammonia derivatives. m Elemental, white (yellow), and red. n Tripolyphosphate (100% $Na_5P_3O_{10}$). o Includes tetrabasic (pyro) phosphate. p Soluble silicate glass (water glass), solid and liquid (anhydrous); excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates. q Anhydrous, high and low purity, and Glauber's salt. r Gross (new and fortified). s Composite and pure. **Sources:** Department of Commerce, International Trade Commission

SYNTHETIC FIBERS: **Only nylon and polyolefins grow, and those modestly**

Synthetic noncellulosic fibers output



Millions of lb	Production											Annual change	
	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
NONCELLULOSIC FIBERS													
Acrylic[a]	543	588	592	616	631	671	671	624	691	779	761	−8%	−3%
Nylon[b]	2740	2669	2689	2514	2343	2412	2419	1927	2332	2358	2720	3	0
Olefin[c]	1639	1588	1494	1393	1249	997	906	723	785	748	759	3	8
Polyester	3594	3681	3541	3305	3341	3392	3544	3196	4176	3989	4178	−2	−1
CELLULOSIC FIBERS													
Acetate[d]	580	614	605	619	558	199	229	196	261	316	324	−6	−5
Rayon						421	401	388	509	490	606		
TOTAL	**9096**	**9140**	**8921**	**8447**	**8122**	**8092**	**8168**	**7027**	**8754**	**8680**	**9348**	**0**	**0**

a Includes modacrylic. b Excludes aramid in 1983–87. c Includes olefin yarn and monofilaments and olefin and vinyon staple, tow, and fiberfill. d Includes diacetate and triacetate; excludes production for cigarette filters. **Source:** Fiber Economics Bureau

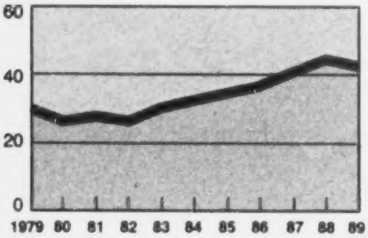
SYNTHETIC RUBBER: Growth of recent years leveled off in 1989

Thousands of metric tons	Production 1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	1979–89
Ethylene-propylene	260	263	254	230	215	215	175	123	178	144	175	−1%	4%
Nitrile	69	76	69	59	53	67	55	45	66	63	75	−9	−1
Polybutadiene	411	407	371	336	330	359	333	288	342	311	397	1	0
Styrene-butadiene rubber	874	909	850	792	735	958	904	876	1032	1074	1378	−4	−5
Other[a]	688	679	638	596	505	556	468	498	404	423	509	1	3
TOTAL	**2302**	**2335**	**2182**	**2013**	**1838**	**2155**	**1935**	**1830**	**2022**	**2015**	**2534**	1%	−1%

a Includes butyl, polychloroprene, polyisoprene, silicone, and other synthetic elastomers. Some values are estimated. **Source:** Rubber Manufacturers Association

Plastics production

Billions of lb

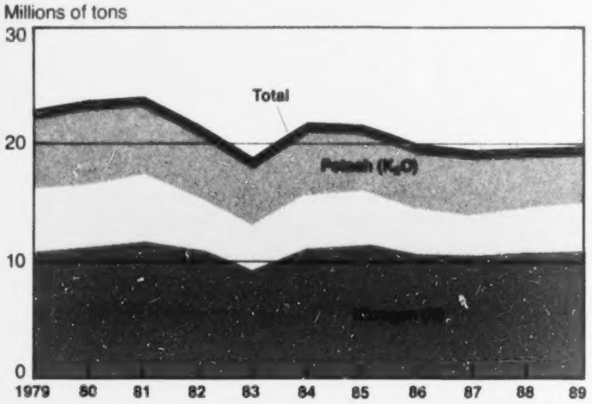


PLASTICS: Production of major resins generally declined last year

Millions of lb[a]	Production 1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	1979–89
THERMOSETTING RESINS													
Epoxy[b]	510	486	433	398	385	406	334	286	336	315	361	5%	4%
Melamine	222	207	212	173	192	210	180	158	179	167	200	7	1
Phenolic[c]	2,879[d]	3,066[d]	2,869[d]	2,735[d]	2,621[d]	2,502[d]	2,477[d]	2,006[d]	2,333[d]	1,499	1,781	−6	nc
Polyester[e]	1,319	1,404	1,367	1,271	1,223	1,232	1,084	865	997	947	1,147	−6	4
Urea	1,477	1,425	1,382	1,271	1,210	1,199	1,172	998	1,165	1,165	1,367	4	1
TOTAL	**6,407**	**6,588**	**6,263**	**5,848**	**5,631**	**5,549**	**5,247**	**4,313**	**5,010**	**4,093**	**4,856**	−3	nc
THERMOPLASTIC RESINS													
Polyethylene													
Low density[f]	9,695	10,397	9,599	8,903	8,889	8,413	8,041	7,503	7,693	7,291	7,793	−7	2
High density[g]	8,102	8,400	7,995	7,182	6,671	6,085	5,689	4,928	4,695	4,405	5,010	−4	5
Polypropylene	7,238	7,274	6,647	5,812	5,139	4,940	4,433	3,477	3,955	3,648	3,841	0	7
Styrene polymers													
Polystyrene	5,104	5,187	4,780	4,470	4,054	3,838	3,570	3,191	3,621	3,521	4,005	−2	2
Styrene-acrylonitrile	113	148	126	92	87	99	93	91	107	111	124	−24	−1
Acrylonitrile-butadiene-styrene and other styrene polymers[h]	2,394	2,418	2,254	2,196	2,036	2,127	1,889	1,380	1,745	1,705	2,107	−1	1
Polyamide, nylon type	569	566	507	465	399	396	321	228	312	274	327	1	6
Vinyl resins													
Polyvinyl chloride and copolymers	8,478	8,350	7,971	7,256	6,772	6,760	6,067	5,326	5,707	5,470	6,119	2	3
Other vinyl resins[i]	220	222	212	195	190	187	186	177	208	196	220	−1	0
Thermoplastic polyester	1,630	1,652	1,394	1,175	965	899	778	648	609	na	na	−1	na
TOTAL	**43,543**	**44,614**	**41,485**	**37,746**	**35,202**	**33,744**	**31,067**	**26,949**	**28,652**	**26,621**	**29.546**	−2%	4%

Note: Totals are for those products listed and exclude some small-volume plastics. a Dry-weight basis unless otherwise specified. b Unmodified. c Includes other tar acid resins. d Gross-weight basis. e Unsaturated. f Density 0.940 and below. g Density above 0.940. h Includes styrene-butadiene copolymers and other styrene-based polymers. i Includes polyvinyl butyral, polyvinyl formal, and polyvinylidene-chloride. na = not available. nc = not comparable. **Source:** Society of the Plastics Industry

Fertilizer consumption



Note: Years ending June 30. **Sources:** Department of Agriculture. Fertilizer Institute

FERTILIZERS:
Consumption held steady for major nutrients in 1989 crop year

	Consumption											Annual change	
Thousands of tons	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
Nitrogen (N)	10,633	10,475	10,210	10,424	11,493	11,092	9,127	10,983	11,924	11,407	10,715	2%	0%
Phosphates (P_2O_5)	4,124	4,112	4,013	4,178	4,658	4,901	4,138	4,814	5,434	5,432	5,606	0	−3
Potash (K_2O)	4,833	4,943	4,852	5,053	5,553	5,797	4,831	5,631	6,320	6,245	6,245	−2	−3
Total	**19,590**	**19,530**	**19,214**	**19,655**	**21,704**	**21,790**	**18,096**	**21,428**	**23,678**	**23,083**	**22,565**	0%	−1%

Note: Years end June 30. **Source:** Fertilizer Institute

FERTILIZER PRODUCTION: Phosphates output rose while several nitrogen products declined

								Annual change	
Thousands of tons	1989	1988	1987	1986	1985	1984	1983	1988–89	1983–89
NITROGEN PRODUCTS									
Ammonia	14,192	14,136	13,357	12,565	16,594	16,613	13,361	0%	1%
Ammonium nitrate	2,528	2,765	2,472	2,250	3,178	3,365	3,232	−9	−4
Ammonium sulfate	2,327	2,260	2,153	2,058	2,343	2,078	1,969	3	3
Urea	4,253	4,501	4,253	3,564	3,975	4,889	4,112	−6	1
Nitrogen solutions	5,644	6,999	5,988	5,945	7,928	7,999	6,385	−19	−2
PHOSPHATE PRODUCTS									
Diammonium phosphate	13,507	11,575	9,537	7,492	10,800	12,358	10,264	17	5
Monoammonium phosphate	1,991	1,818	1,679	1,416	1,641	1,654	1,423	10	6
Concentrated superphosphate	1,777	2,032	2,049	2,127	2,570	2,404	2,684	−13	−7
Phosphate rock	47,676	42,220	39,330	36,227	49,348	47,465	40,664	13	3
Phosphoric acid (P_2O_5)	10,962	10,234	8,903	8,085	9,837	10,899	9,182	7	3
POTASH PRODUCTS									
Potassium chloride	2,316	2,243	1,810	1,715	1,713	2,168	1,928	3	3

Note: Figures are based on Fertilizer Institute surveys and may not represent the entire industry. **Source:** Fertilizer Institute

CIRCLE 45 ON READER SERVICE CARD →

PESTICIDES: Overall production grew strongly last year, led by major gains for herbicides

Millions of lb	Production											Annual change	
	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1987–88	1978–88
Herbicides[a]	702	556	725	756	716	604	623	839	806	657	664	26%	1%
Insecticides[b]	352	379	342	370	350	306	379	448	506	617	605	−7	−5
Fungicides[c]	110	105	113	109	123	106	111	143	156	155	148	5	−3
TOTAL	**1164**	**1040**	**1180**	**1235**	**1189**	**1017**	**1113**	**1430**	**1468**	**1429**	**1416**	**12%**	**−2%**

a Includes plant growth regulators. b Includes rodenticides, soil conditioners, and fumigants. c Includes dithiocarbamates. **Source:** International Trade Commission

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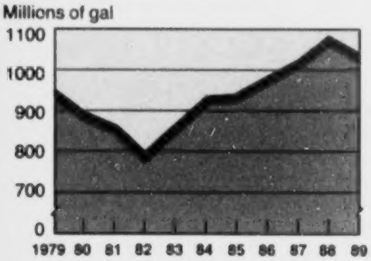
Paints and coatings shipments



COATINGS: Volume down in 1989 after six years of steady growth

Millions of gal	Shipments											Annual change	
	1989[a]	1988[a]	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
Architectural	533	532	527	501	477	457	433	374	417	439	472	0%	1%
Product[b]	337	393	340	350	317	336	294	280	312	316	351	−14	0
Special purpose	167	162	145	136	145	145	130	129	129	135	116	3	4
TOTAL	**1037**	**1086**	**1013**	**987**	**939**	**938**	**857**	**783**	**858**	**890**	**939**	**−5%**	**1%**

a Preliminary. b For original equipment manufacturers. **Source:** Department of Commerce

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AEROSOLS: Decline in personal products volume offsets gains in other areas

Millions of units	Production											Annual change	
	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
Personal products	1015	1100	964	952	879	832	747	628	645	637	772	−8%	3%
Household products	680	650	640	635	630	603	586	556	575	580	653	5	0
Automotive and industrial products	475	440	379	375	342	337	303	286	302	310	300	8	5
Paints and finishes	350	331	307	297	290	307	300	295	313	310	302	6	1
Insect sprays	197	190	190	193	190	184	180	166	173	150	199	4	0
Food products	175	157	140	136	140	138	132	131	145	130	141	11	2
Animal products	8	8	22	22	15	16	19	19	14	15	18	0	−8
Miscellaneous	12	31	80	18	23	15	15	13	28	30	14	−61	−2
TOTAL	**2912**	**2907**	**2722**	**2628**	**2509**	**2432**	**2282**	**2094**	**2195**	**2162**	**2399**	**0%**	**2%**

Source: Chemical Specialties Manufacturers Association

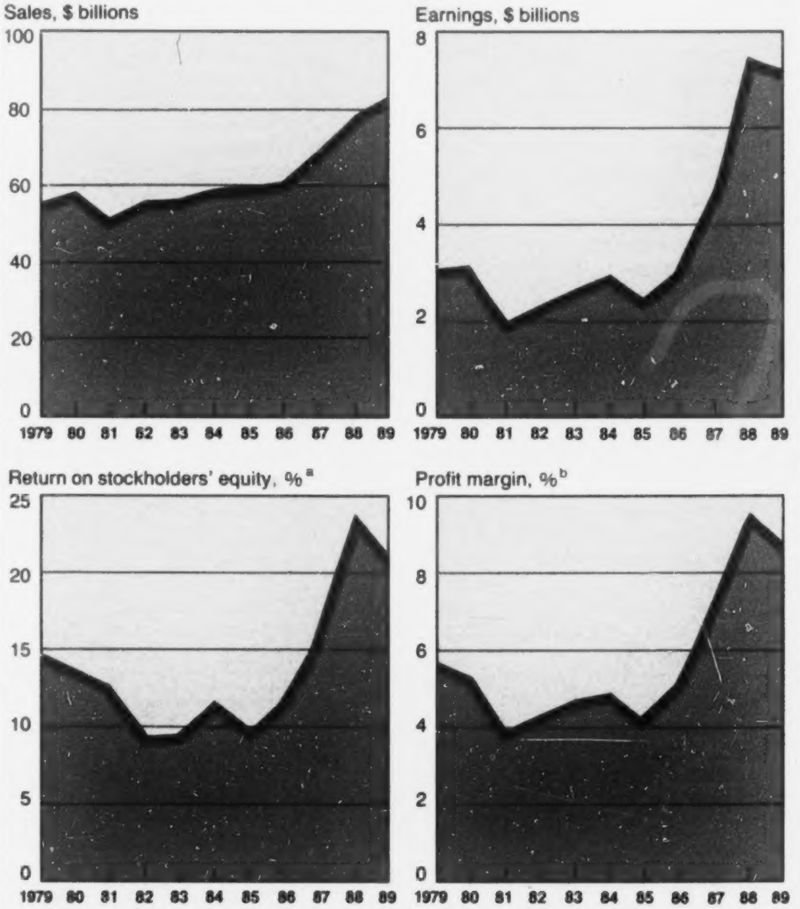
CHLOROFLUOROCARBONS: Production drops for all major types

Millions of lb	Production											Annual change	
	1989[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
Chlorodifluoromethane (F-22)	327	333	275	271	235	254	236	174	252	227	211	−2%	4%
Dichlorodifluoromethane (F-12)	392	414	335	322	302	337	290	258	325	295	294	−5	3
Trichlorofluoromethane (F-11)	193	249	198	202	176	185	215	140	163	158	167	−22	1
All other fluorinated hydrocarbons[b]	na	379	354	344	306	337	279	na	na	na	202	na	na
TOTAL	**na**	**1374**	**1162**	**1139**	**1019**	**1113**	**1020**	**na**	**na**	**na**	**874**	**na**	**na**

a Preliminary. b Includes other fluorohalogenated hydrocarbons. na = not available. **Source:** International Trade Commission

Earnings growth stalls for chemical industry

As the upsurge in earnings ends, profitability is trimmed for major chemical firms



Note: Based on data for 30 major chemical companies. a After-tax earnings as a percentage of year-end stockholders' equity. b After-tax earnings as a percentage of sales.

Nobody expected expansion in the chemical industry to last forever. So after profits increased for six of the past seven years—frequently at rates in the double digits—it was no surprise that the heady pace should slow last year. However, the change in trend was nowhere near so bad as many industry observers had feared it might be. And all signs so far this year point to another round of highly respectable profits.

Last year started off looking like a continuation of good times. Prices and production were holding up well enough to continue strong earnings growth through the first quarter. But by the year's second three months, growth had moderated considerably. By the third quarter, declines started showing up in year-to-year comparisons. Then the final period turned the earlier record upside down, with chemical companies registering declines in earnings in the range of 30%.

The result was that while sales continued to increase—up almost 6% for the full year for the 30 companies regularly sampled by C&EN—earnings during all of 1989 for these firms declined about 6% from the previous year. However, despite the drop, chemical company earnings, as tallied by C&EN, were still far higher last year than any year prior to 1988.

The same pattern held true for profitability. Although both profit margins and returns on equity fell last year from the year before, these two measures of company financial performance were higher in 1989 than anytime other than 1988 since 1975. The average profit margin for C&EN's 30-company sample fell to 8.6% of sales in 1989 from 9.6% the year before. And return on stockholders' equity dropped to 20.2% from 23.5% in 1988.

The underlying reason for this decline was largely—but not entirely—a continued weakness in such major markets for chemicals as housing, automobiles and other consumer durable goods, and agriculture.

Softness in these areas led to an increase in chemical production of merely 3% over 1988. And prices, although rising almost 6% for the year as a whole, were slipping significantly during the latter part of 1989. By the end of the year, the producer price index for chemicals and allied products was down 2% from the level where it started the year.

Industry analysts note, too, that while exports of chemicals remained at a high level, the prices that producers were garnering for those exports dropped considerably.

Also contributing to a decline in earnings last year was an increase in debt service costs for many chemical companies. As firms finally began plant expansions, they took on an increased debt load, which resulted in higher interest payments and other charges that ate into earnings.

TOP 100 CHEMICAL PRODUCERS: Half of them sold $1 billion or more of chemicals last year

Rank 1989	Rank 1988		Chemical sales 1989 ($ millions)	Change from 1988	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1988	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$15,249	3.6%	42.9%	Diversified	$2769	6.0%	57.0%	18.2%	$12,514	36.0%	22.1%
2	2	**Dow Chemical**	14,179	4.0	80.6	Basic chemicals	3543	−2.5	88.4	25.0	12,202	55.0	29.0
3	3	**Exxon**	10,559	5.7	11.1	Petroleum	1609	−13.6	19.2	15.2	7,118	8.6	22.6
4	4	**Union Carbide**	7,962[d]	4.7	91.1	Basic chemicals	1225	−20.6	96.5	15.4	6,172	72.2	19.8
5	5	**Monsanto**	5,782	4.5	66.6	Basic chemicals	929	2.1	86.2	16.1	4,482	52.1	20.7
6	6	**Hoechst Celanese**	5,658	5.4	94.0	Basic chemicals	576	2.3	114.7	10.2	na	na	na
7	7	**Occidental Petroleum**	5,203	11.3	25.9	Petroleum	1235	17.6	260.0	23.7	5,508	26.6	22.4
8	12	**General Electric**	4,929[d]	39.3	9.0	Diversified	1057	44.2	15.5	21.4	8,023	6.3	13.2
9	8	**BASF**	4,461	6.0	82.3	Basic chemicals	na	na	na	na	na	na	na
10	9	**Amoco**	4,274	−1.8	17.8	Petroleum	744	−27.2	21.6	17.4	3,158	10.4	23.6
11	10	**Mobil**	4,039	−5.6	7.3	Petroleum	774	−9.0	16.8	19.2	2,702	6.9	28.6
12	11	**Shell Oil**	3,833	−4.3	16.2	Petroleum	941	26.1	37.9	24.5	3,824	13.9	24.6
13	15	**Eastman Kodak**	3,522	16.1	19.1	Photo equipment	643	2.4	40.4	18.3	3,238	13.7	19.9
14	13	**Chevron**	3,328	3.9	10.4	Petroleum	532	−13.6	29.5	16.0	2,476	7.3	21.5
15	14	**W. R. Grace**	3,256	4.0	53.2	Specialty chemicals	406	4.6	66.0	12.5	2,436	43.4	16.7
16	16	**Allied-Signal**	2,993	−1.3	25.1	Diversified	355	−5.8	37.5	11.9	1,879	18.5	18.9
17	17	**Arco Chemical**	2,663	−1.4	100.0	Basic chemicals	580	−19.7	100.0	21.8	2,655	100.0	21.8
18	18	**Rohm & Haas**	2,661	5.0	100.0	Basic chemicals	287	−23.9	100.0	10.8	2,128	86.7	13.5
19	20	**Air Products**[e]	2,481	10.9	93.9	Basic chemicals	425	3.8	109.5	17.1	2,835	84.2	15.0
20	19	**Phillips Petroleum**	2,449	−2.7	19.8	Petroleum	652	−28.4	46.9	26.6	1,377	12.2	47.3
21	23	**Bayer USA**	2,300	7.5	42.4	Diversified chemicals	127[f]	7.6	82.5	5.5	na	na	na
22	22	**American Cyanamid**	2,241	3.4	46.4	Basic chemicals	236	10.0	40.7	10.5	1,779	35.8	13.2
23	24	**Ashland Oil**[e]	2,230	6.7	26.3	Petroleum	98	−3.9	34.8	4.4	744	16.7	13.2
24	21	**Quantum Chemical**	2,015	−9.2	75.4	Basic chemicals	423	−40.5	89.0	21.0	1,830	60.9	23.1
25	25	**B. F. Goodrich**	1,977	−4.7	81.7	Basic chemicals	261	−15.4	95.0	13.2	1,467	64.5	17.8
26	—	**Lyondell Petrochemical**	1,905	0.1	35.6	Petroleum	na	na	na	na	na	na	na
27	28	**Texaco**	1,818	6.3	5.6	Petroleum	399	5.3	11.6	21.9	1,126	4.4	35.4
28	—	**Atochem**	1,778	206.0	100.0	Basic chemicals	na	na	na	na	na	na	na
29	38	**Aluminum Co. of America**	1,700	39.9	15.6	Nonferrous metals	na	na	na	na	2,500	21.7	0
30	27	**Hercules**	1,632	−4.2	52.8	Basic chemicals	126	−0.8	62.5	7.7	1,294	35.4	9.7
31	37	**Akzo**	1,612	19.7	100.0	Basic chemicals	117	54.4	100.0	7.3	na	na	na
32	35	**Rhône-Poulenc**	1,600	14.3	100.0	Specialty chemicals	na	na	na	na	na	na	na
33	32	**Dow Corning**	1,575	6.6	100.0	Specialty chemicals	163[f]	8.2	100.0	10.3	na	na	na
34	34	**National Starch**	1,569	10.9	100.0	Specialty chemicals	226	13.2	100.0	14.4	1,269	100.0	17.8
35	33	**FMC**	1,542	7.4	45.1	Machinery	220	−1.5	55.5	14.3	1,329	47.1	16.6
36	30	**Ethyl**	1,520	−9.2	62.5	Basic chemicals	283	−8.5	69.4	18.6	1,055	18.7	26.8
37	31	**BP America**	1,426	−5.4	8.1	Petroleum	68	−34.6	3.3	4.8	na	na	na
38	36	**Olin**	1,285	−5.9	51.2	Basic chemicals	174	65.7	76.7	13.5	936	49.2	18.6
39	39	**Unocal**	1,276	6.0	11.6	Petroleum	74	−59.3	12.8	5.8	622	6.7	11.9
40	—	**Tenneco**	1,224	0.5	8.7	Petroleum	119	−1.7	8.5	9.7	1,229	7.2	9.7
41	44	**IMC Fertilizer**[g]	1,222	12.5	100.0	Agrochemicals	257	17.7	100.0	21.1	1,678	100.0	15.3
42	40	**Huntsman Chemical**	1,200	0	100.0	Basic chemicals	na	na	na	na	na	na	na
42	43	**Ciba-Geigy**	1,200[h]	9.3	34.3	Specialty chemicals	na	na	na	na	na	na	na
44	42	**PPG Industries**	1,175	5.6	20.5	Glass products	257	0.8	35.2	21.9	1,033	18.3	24.9
45	47	**Lubrizol**	1,124	8.5	92.1	Specialty chemicals	321	4.8	90.2	28.5	733	76.3	43.8
46	41	**Freeport-McMoRan**	1,105	−2.3	95.6	Agrochemicals	108	−45.3	82.1	9.8	876	72.2	12.3
46	46	**Georgia Gulf**	1.105	4.1	100.0	Basic chemicals	300	−3.9	100.0	27.2	473	100.0	63.4
48	51	**Nalco Chemical**	1,071	7.7	100.0	Specialty chemicals	181	14.1	100.0	16.9	939	100.0	19.3
49	49	**NL Industries**	1,001	−0.6	100.0	Basic chemicals	278	6.5	100.0	27.8	na	na	na
50	50	**Solvay America**	1,000[d]	0	100.0	Basic chemicals	na	na	na	na	na	na	na

2 Finances of the U.S. Chemical Industry

Rank 1989	Rank 1988		Chemical sales 1989 ($ millions)	Change from 1988	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1988	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	45	**Aristech**	$996	−6.5%	100.0%	Basic chemicals	$140	−28.9%	100.0%	14.0%	$ 721	100.0%	19.4%
52	54	**Cabot[e]**	951	5.2	49.1	Basic chemicals	112	−31.6	176.7	11.7	790	55.7	14.1
53	56	**Terra Chemicals**	949	11.9	100.0	Agrochemicals	na	na	na	na	na	na	na
54	55	**Morton International[g]**	935	7.0	66.5	Specialty chemicals	144	−3.0	69.6	15.4	861	63.1	16.8
55	60	**Farmland Industries[i]**	903	17.7	30.3	Agricultural supplies	90	20.3	50.6	10.0	382	32.3	23.6
56	—	**Degussa**	886	na	51.4	Specialty chemicals	na	na	na	na	na	na	na
57	57	**International Flavors**	870	3.6	100.0	Specialty chemicals	223	6.6	100.0	25.7	684	70.6	32.6
58	52	**CF Industries**	856	−10.6	100.0	Agrochemicals	27	−75.1	100.0	3.2	798	100.0	3.4
59	63	**Engelhard**	813	11.9	33.8	Diversified	96	−10.3	79.0	11.8	888	66.3	10.8
60	62	**Uniroyal Chemical**	805	9.6	100.0	Specialty chemicals	na	na	na	na	na	na	na
61	68	**Great Lakes Chemical**	792	42.0	100.0	Specialty chemicals	202	40.6	100.0	25.5	1,097	100.0	18.4
62	59	**Vista Chemicals[e]**	779	−0.3	100.0	Basic chemicals	227	16.8	100.0	29.2	567	100.0	40.1
63	—	**Nova**	778	44.3	100.0	Basic chemicals	na	na	na	na	na	na	na
64	61	**Witco**	766[h]	1.0	48.2	Specialty chemicals	18	−71.4	24.2	2.3	377	33.1	4.7
65	65	**H. B. Fuller[j]**	753	10.0	100.0	Specialty chemicals	46	−0.9	100.0	6.1	455	100.0	10.1
66	66	**American Petrofina**	662	−2.9	21.8	Petroleum	138	−50.7	69.4	20.9	435	17.3	31.9
67	53	**International Minerals[g]**	640	−31.3	65.1	Agrochemicals	50	−57.4	37.7	7.8	673	34.1	7.4
68	70	**GAF**	600	10.1	59.4	Specialty chemicals	171	13.9	93.9	28.5	na	na	na
69	71	**Kerr-McGee**	592	14.3	19.2	Petroleum	125	22.5	40.7	21.1	794	23.8	15.7
70	64	**Sterling Chemical[e]**	581	−16.9	100.0	Basic chemicals	156	−49.9	100.0	26.9	329	100.0	47.5
71	—	**Atlas Powder**	543	11.9	100.0	Explosives	na	na	na	na	na	na	na
72	77	**Betz Laboratories**	517	15.4	100.0	Specialty chemicals	88	15.1	100.0	16.9	369	100.0	23.7
73	75	**Sun Co.**	510	10.6	4.6	Petroleum	na	na	na	na	na	na	na
74	72	**Pfizer**	509	−0.6	9.0	Drugs	39	−20.2	4.1	7.7	538	6.5	7.2
75	76	**Hoffmann-La Roche**	500[k]	11.1	22.7	Drugs	na	na	na	na	na	na	na
76	74	**Merck**	492	5.6	7.5	Drugs	59	−3.6	2.7	12.0	470	7.0	12.6
77	78	**Ferro**	478	7.8	44.1	Specialty materials	17	−6.0	18.2	3.6	251	37.5	6.8
78	69	**Borden Chemicals**	466	−15.7	100.0	Basic chemicals	95	−39.0	99.7	20.4	550	100.0	17.3
79	80	**Loctite[g]**	457	9.5	100.0	Specialty chemicals	80	21.1	100.0	17.5	362	100.0	22.0
80	82	**Lonza**	450	13.9	100.0	Specialty chemicals	na	na	na	na	na	na	na
81	79	**Dexter**	439	3.4	51.7	Specialty chemicals	31	20.5	33.1	7.1	310	44.6	10.1
82	83	**Vulcan Materials**	430	12.5	40.0	Nonmetallic minerals	86	30.7	42.9	20.1	na	na	na
83	81	**Union Camp**	413	3.7	15.0	Diversified	14	−54.8	2.7	3.3	289	8.5	4.7
84	85	**Sigma-Aldrich**	359	18.9	81.4	Specialty chemicals	87	12.8	86.9	24.2	418	88.5	20.7
85	84	**Stepan**	346	4.0	100.0	Specialty chemicals	12	−43.1	100.0	3.4	215	100.0	5.4
86	89	**First Mississippi[g]**	308	29.5	70.9	Agrochemicals	27	16.0	82.3	8.7	166	34.7	16.2
87	90	**Crompton & Knowles**	281	20.9	79.0	Specialty chemicals	36	37.0	71.4	12.9	170	78.2	21.2
88	87	**Chemed**	277	2.7	52.3	Specialty chemicals	38	14.3	67.4	13.8	137	40.7	28.0
89	86	**Petrolite[l]**	275	0.2	94.3	Specialty chemicals	19	−12.3	217.6	6.7	191	79.6	9.7
90	91	**Calgon Carbon**	253	12.1	100.0	Basic chemicals	57	10.8	100.0	22.4	234	100.0	24.3
90	88	**Georgia-Pacific**	253	5.0	2.5	Wood products	na	na	na	na	na	na	na
92	93	**Mississippi Chemical[g]**	209	12.4	100.0	Farm cooperative	47	157.7	100.0	22.5	577	100.0	8.1
93	92	**Sherex**	188	−6.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
94	94	**Quaker Chemical**	182	9.0	100.0	Specialty chemicals	23	32.5	100.0	12.7	109	83.3	21.0
95	95	**LeaRonal[m]**	157	0	100.0	Specialty chemicals	16	15.2	100.0	10.3	88	100.0	18.3
96	—	**Nu-West[g]**	155	176.3	100.0	Agrochemicals	−3	def	def	def	170	100.0	def
97	—	**Eagle-Picher**	152[d]	−21.3	20.9	Diversified	15	−35.1	36.9	9.7	86	17.8	17.3
98	96	**Lawter International**	136	8.1	100.0	Specialty chemicals	23	−17.8	100.0	16.5	134	100.0	16.8
99	99	**Cambrex Corp.**	131	8.9	100.0	Specialty chemicals	7	−48.6	100.0	5.0	129	100.0	5.1
100	98	**Agway**	118[k]	−4.3	3.7	Farm cooperative	na	na	na	na	na	na	na

a Operating income is sales less administrative expenses and cost of sales. b Chemical operating profit as a percentage of chemical sales. c Chemical operating profit as a percentage of identifiable chemical assets. d Chemical sales include significant amounts of nonchemical products. e Fiscal year ended Sept. 30. f Chemical net income. g Fiscal year ended June 30. h Does not include all chemical sales. i Fiscal year ended Aug. 31. j Fiscal year ended Nov. 30. k C&EN estimate. l Fiscal year ended Oct. 31. m Fiscal year ended Feb. 28, 1989.

FINANCIAL ANALYSIS: **By several measures, chemical company performance declined in 1989**

									CAPITAL SPENDING[f]				Net plant
		Profit margin[a]	Return on investment[b]	Debt as % of debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	as % of sales	as % of net plant	R&D as % of sales	Sales as % of assets	as % of gross plant
SALES OVER $1 BILLION													
Air Products[g]	1989	8.4%	4.3%	37.1%	23.6%	30.8%	$187	31.2%	15.7%	18.7%	2.7%	78.5%	49.9%
	1988	8.8	4.5	34.4	24.0	29.9	183	28.2	16.8	19.9	3.0	81.1	50.5
American Cyanamid	1989	6.1	5.0	16.5	38.6	24.6	136	41.1	8.2	22.6	8.4	97.1	51.4
	1988	6.7	5.6	18.9	38.3	24.3	129	34.1	8.1	24.0	8.0	100.0	49.8
Cabot[g]	1989	0.9	1.0	44.1	32.8	12.7	352	166.1	9.9	25.9	1.8	136.7	56.1
	1988	3.6	2.8	34.5	36.8	9.6	322	40.5	10.1	20.3	1.7	108.6	52.1
Dow Chemical	1989	14.1	10.1	32.6	54.1	44.9	283	23.2	9.6	22.2	5.0	79.4	44.1
	1988	14.4	11.1	31.5	55.1	53.5	301	19.1	10.0	25.4	4.6	102.7	42.8
Ethyl	1989	14.4	13.2	35.6	31.3	3.8	276	26.3	7.8	20.5	4.0	27.0	48.8
	1988	11.5	11.0	35.0	21.5	3.6	193	22.5	7.5	21.0	2.9	38.3	49.3
Georgia Gulf	1989	17.4	35.3	66.1	na	na	818	12.5	4.9	25.9	na	233.5	69.7
	1988	18.3	38.3	14.2	na	na	776	8.6	2.4	14.8	na	231.9	69.0
B. F. Goodrich	1989	7.1	6.3	18.5	26.7	18.6	203	34.6	9.9	24.2	2.7	106.4	59.6
	1988	8.7	8.1	21.1	28.4	18.5	196	24.8	7.5	19.3	2.4	116.6	58.3
W. R. Grace	1989	4.2	3.9	48.6	34.8	31.0	132	46.6	7.9	21.8	2.0	108.8	49.6
	1988	4.0	3.8	49.3	37.0	28.6	127	52.1	7.2	20.6	2.1	109.0	49.8
Hercules	1989	def	def	23.3	25.4	17.0	133	def	9.5	20.7	2.5	84.6	48.4
	1988	4.3	3.1	17.3	22.6	13.3	123	77.1	9.0	21.6	2.7	84.3	49.6
Lubrizol	1989	7.7	6.9	7.4	52.4	40.3	230	54.8	5.3	20.4	5.7	127.1	39.0
	1988	11.7	10.1	7.7	53.6	35.1	234	48.0	4.9	18.3	5.8	115.1	40.8
Monsanto	1989	7.8	6.7	27.2	35.6	28.5	206	32.5	7.0	19.1	6.9	100.9	45.7
	1988	7.1	5.9	27.0	37.1	27.4	182	35.7	7.1	18.8	7.8	98.0	45.4
Morton International[h]	1989	6.9	6.5	4.6	31.1	26.4	167	na	9.4	23.8	2.7	103.1	59.7
	1988	9.3	9.2	5.5	30.0	30.3	160	na	7.8	20.4	2.8	105.9	59.1
Nalco Chemical	1989	11.2	10.8	32.5	27.1	19.4	195	47.9	8.1	24.6	3.8	114.1	48.7
	1988	10.7	10.8	17.4	27.8	20.4	185	47.6	6.2	19.8	3.7	118.5	48.0
Olin	1989	4.9	4.2	36.1	7.2	9.3	163	34.7	5.7	18.2	2.6	131.8	36.0
	1988	4.2	3.3	33.8	10.1	9.2	141	36.7	6.4	18.4	2.5	119.0	37.0
PPG Industries	1989	8.1	6.2	33.3	30.9	29.7	162	35.6	9.4	17.9	4.1	101.6	55.2
	1988	8.3	6.8	27.2	30.0	28.8	155	30.0	7.3	14.9	4.0	109.0	55.1
Quantum	1989	4.3	3.4	107.9	na	na	na	1121.1	21.8	33.2	1.7	88.9	70.0
	1988	12.3	11.0	144.0	na	na	na	17.4	11.4	25.5	na	100.5	67.4
Rohm & Haas	1989	6.6	5.2	21.5	43.2	32.1	204	43.8	14.5	33.5	6.6	108.4	47.9
	1988	9.1	7.4	19.3	42.8	30.2	204	29.1	13.3	36.1	6.2	113.1	45.3
Union Carbide	1989	6.6	4.7	46.6	33.7	40.7	190	24.4	9.0	17.1	2.1	102.3	48.1
	1988	8.0	5.6	55.6	30.8	36.9	189	23.4	8.1	15.2	1.9	98.6	49.0
Witco	1989	2.2	2.3	29.2	18.9	16.4	216	103.3	4.4	16.9	1.6	139.4	48.3
	1988	4.5	4.9	29.4	19.5	15.1	209	43.5	4.5	18.0	1.5	142.3	48.7
MEDIAN 1989		6.9%	5.2%	32.6%	31.3%	26.4%	$199	35.2%	9.0%	21.8%	2.7%	103.1%	48.8%
MEDIAN 1988		8.7%	6.8%	27.2%	30.0%	27.4%	$184	32.1%	7.5%	19.9%	2.9%	108.6%	49.6%

2 Finances of the U.S. Chemical Industry

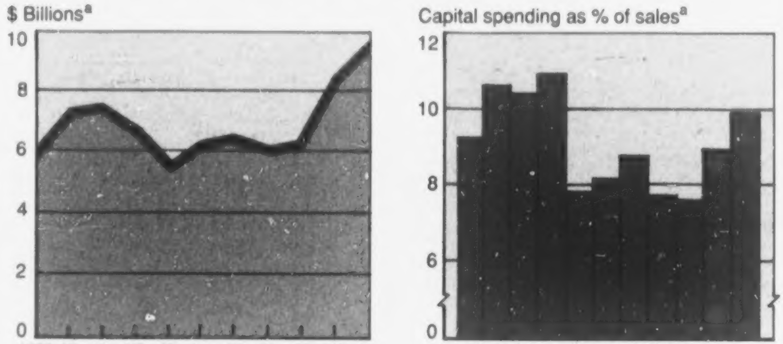
									CAPITAL SPENDING[f]				
		Profit margin[a]	Return on investment[b]	Debt as % of debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	as % of sales	as % of net plant	R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
SALES LESS THAN $1 BILLION													
Betz Laboratories	1989	10.8%	12.1%	35.2%	17.8%	18.9%	$151	55.4%	10.2%	30.7%	3.7%	139.9%	54.6%
	1988	10.8	12.2	0.0	18.0	20.0	142	50.8	9.7	28.4	3.6	140.5	55.7
Calgon Carbon	1989	13.9	13.3	9.9	37.3	30.7	191	12.5	10.4	25.8	1.9	108.4	75.5
	1988	13.0	13.6	18.3	34.4	35.1	na	7.1	7.1	18.7	2.0	115.2	77.7
Cambrex	1989	2.3	2.3	20.3	17.5	na	na	9.1	5.8	15.4	2.9	101.9	68.6
	1988	5.8	6.0	6.7	17.6	na	na	0.0	6.3	19.7	2.6	107.4	68.4
Chemed	1989	4.9	9.8	41.5	11.0	11.8	93	70.6	2.7	21.4	0.6	158.1	56.5
	1988	4.7	8.3	44.8	12.7	11.1	80	77.3	3.3	24.0	0.7	137.4	58.0
Crompton & Knowles	1989	6.9	11.2	29.4	17.3	21.5	212	27.9	3.8	26.4	2.2	163.3	56.1
	1988	5.8	8.4	35.2	18.4	21.2	181	30.1	2.4	16.1	2.1	140.9	55.4
First Mississippi[h]	1989	3.8	2.1	30.6	17.7	na	na	34.6	24.7	38.2	na	90.8	44.8
	1988	10.2	5.7	1.8	25.1	na	na	14.8	19.0	36.2	na	96.3	35.2
H. B. Fuller[i]	1989	2.1	3.1	35.1	44.9	50.8	140	34.9	5.4	21.9	2.1	165.5	63.5
	1988	3.1	4.5	35.5	46.3	50.1	132	23.7	5.9	24.9	2.1	157.7	63.4
Great Lakes Chemical	1989	15.5	13.2	16.1	40.1	49.6	na	11.1	5.1	14.7	3.4	72.2	56.6
	1988	18.5	16.3	3.8	17.9	12.8	na	11.8	8.4	20.1	3.4	84.0	57.3
International Flavors	1989	15.9	11.9	0.0	69.2	47.0	206	52.6	3.8	14.1	6.0	89.7	53.1
	1988	15.3	12.1	0.0	70.1	48.0	201	47.1	4.8	17.6	5.9	95.2	55.1
International Minerals[h]	1989	11.2	7.1	44.5	25.8	10.4	142	33.5	8.4	17.1	6.6	49.9	69.5
	1988	7.1	7.1	25.9	17.3	14.5	213	41.0	5.5	18.2	4.4	82.0	71.1
Loctite[h]	1989	11.9	14.0	13.8	57.9	62.0	130	26.4	3.5	22.8	3.8	126.1	53.7
	1988	10.0	11.4	16.1	58.4	62.2	127	23.7	3.5	19.8	3.5	120.2	57.1
Petrolite[j]	1989	2.4	2.0	1.1	30.5	35.0	na	178.1	6.5	18.0	4.1	121.5	44.0
	1988	4.3	3.7	2.2	30.2	34.3	na	97.5	6.8	19.6	4.1	124.7	44.7
Quaker	1989	7.1	8.9	5.9	43.4	32.1	185	29.8	4.2	20.7	na	138.2	53.0
	1988	7.0	8.9	5.7	40.6	30.7	170	29.6	3.2	16.1	5.5	137.6	52.9
Sigma-Aldrich	1989	14.5	12.0	17.1	21.9	26.4	116	14.3	11.7	29.3	na	93.4	71.3
	1988	15.0	13.9	6.0	18.0	15.4	117	14.4	9.5	29.8	na	104.3	68.6
Stepan	1989	2.3	2.3	49.2	na	na	301	37.2	9.8	27.8	2.9	160.8	48.7
	1988	4.0	4.6	40.5	na	na	324	19.8	6.1	19.5	3.9	179.4	47.9
Sterling Chemical[g]	1989	17.9	28.6	37.6	35.0	na	na	42.5	9.9	26.6	na	176.5	84.7
	1988	30.6	67.7	48.8	na	na	na	89.0	2.4	9.8	na	237.6	86.7
Vista Chemical[g]	1989	15.4	18.2	141.7	3.4	na	na	20.7	12.7	29.0	na	137.4	71.0
	1988	15.9	21.1	60.2	9.8	na	na	4.3	6.2	17.4	na	150.0	72.0
MEDIAN 1989		10.8%	11.2%	29.4%	28.2%	31.4%	$151	33.5%	6.5%	22.8%	3.2%	126.1%	56.5%
MEDIAN 1988		10.0	8.9	16.1	18.4	26.0	$156	23.7	6.1	19.6	3.5	124.7	57.3

Note: Net income is from continuing operations, excluding extraordinary and nonrecurring items where possible. **a** Net income as a percentage of sales. **b** Net income as a percentage of current assets plus gross plant. **c** Consolidated sales only. **d** Foreign identifiable assets as a percentage of total assets. **e** Thousands of dollars. **f** Actual spending on construction of new facilities and purchase of land and new equipment in consolidated businesses. **g** Fiscal year ended Sept. 30. **h** Fiscal year ended June 30. **i** Fiscal year ended Nov. 30. **j** Fiscal year ended Oct. 31. **na** = not available. **def** = deficit.

Capital spending by U.S. chemical producers continued to rise at a higher than usual rate in 1989. The increase for 1989 over 1988 for the 25 chemical firms that C&EN surveys annually was 16%, a respectable showing although not nearly so good as the 35% jump that 1988 registered over 1987.

Even so, last year's increase was well above the 5% annual compound growth rate during the past 10 years for the companies whose plant outlays are tabulated by C&EN. Among the 25 firms with notable increases in spending last year were Crompton & Knowles, up 86%;

Chemical capital spending nears $10 billion as it rises to the highest level relative to industry sales since 1982



a Worldwide data for 25 major chemical producers. **Source:** Company data

INDUSTRY CAPITAL SPENDING: Spending on chemical plants expands for the third year

$ Billions	1990[a]	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
Chemicals	$ 20.75	$ 20.35	$ 19.25	$ 16.42	$ 16.81	$ 16.44	$ 15.32	$ 12.96	$ 12.66	$ 13.11	$ 11.63
Iron and steel	7.52	6.91	6.16	4.69	3.32	4.12	3.54	3.25	3.78	3.48	3.44
Nonferrous metals	3.25	2.91	2.77	2.16	1.93	1.88	2.13	1.74	1.90	2.51	2.13
Paper	17.20	15.69	11.23	9.01	8.77	8.59	7.21	5.92	5.60	6.11	6.52
Petroleum	25.25	22.97	19.93	17.12	17.92	26.71	25.53	23.14	26.39	25.98	19.57
Rubber	4.18	4.51	3.86	3.52	3.89	3.86	3.11	2.46	2.16	2.15	2.03
Stone, clay, glass	3.79	3.90	3.59	3.37	3.14	3.40	3.09	2.77	2.90	3.41	3.98
All manufacturing	190.89	184.54	165.70	145.90	142.69	153.48	138.82	116.20	120.68	126.54	112.33

a Estimate. **Source:** Department of Commerce

Unspent capital appropriations continue to swell

$ Billions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
Chemicals	$ 11.9	$ 10.6	$ 7.0	$ 6.2	$ 8.0	$ 7.8	$ 7.5	$ 7.4	$ 9.4	$ 9.8	$ 8.5
Iron and steel	2.9	2.7	1.4	0.5	1.1	2.1	2.2	2.7	5.4	3.9	4.5
Nonferrous metals	2.3	1.6	1.7	1.6	2.3	2.5	3.2	3.2	3.7	3.7	2.9
Paper	17.4	12.3	6.3	4.4	4.3	5.9	4.0	5.1	5.1	4.0	4.2
Petroleum	17.1	14.6	15.2	16.7	26.2	24.7	22.3	22.9	29.7	26.7	16.1
Rubber	3.5	2.8	1.7	1.9	3.1	1.6	1.1	1.0	0.9	1.0	0.9
Stone, clay, glass	2.7	2.8	2.4	1.8	2.0	2.2	1.5	1.6	1.9	2.0	2.3
All manufacturing	114.2	101.7	76.8	69.7	95.0	94.4	73.7	70.8	92.7	91.9	76.7

Note: Figures are for fourth quarter of each year. **Source:** Conference Board

Foreign capital outlays by U.S. chemical companies have doubled since 1986

$ Billions[a]	1990[b]	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
Chemicals and allied products	$ 6.2	$ 5.3	$ 4.7	$ 3.7	$ 3.1	$ 2.7	$ 2.4	$ 2.3	$ 2.8	$ 3.0	$ 3.0
Metals, primary and fabricated	2.1	1.5	1.1	0.8	0.9	0.9	1.0	0.9	0.9	0.8	0.9
Petroleum	1.56	14.4	13.3	9.8	9.6	13.7	14.1	15.9	19.7	15.8	14.8
All manufacturing	27.4	23.4	20.8	17.2	16.4	14.9	13.6	13.6	16.8	19.2	19.5

a By majority-owned affiliates of U.S. companies. b Planned. **Source:** Department of Commerce

Quantum Chemical, up 75%; Stepan, up 70%; Quaker Chemical, up 60%; Nalco Chemical, up 39%; B. F. Goodrich, up 33%; and Du Pont, up 26%.

As a percentage of sales, capital spending by the 25 companies as a whole was 9.9% last year, up from 8.9% in 1988. The high for the past decade occurred in 1982, when capital expenditures were 10.9% of sales.

The rate of increase showing up in the much more comprehensive survey of capital expenditures by the chemical industry conducted by the Department of Commerce indicates a more conservative annual increase last year of only 6%. If capital spending increases in 1990 as much as the Commerce Department's survey indicates, chemical producers will boost their outlays just 2% further to a total approaching $21 billion. This figure indicates the industry has scaled back its plant investment plans somewhat in the past few months; an earlier Commerce Department survey had pegged outlays by chemical firms during 1990 at a considerably higher $21.8 billion.

A separate survey by the Conference Board, meanwhile, shows that the backlog of unspent funds ticketed for plant expansion by chemical producers was 12% higher at the end of 1989 than a year earlier, rising to nearly $12 billion.

Although the rate of increase in capital spending appears to have declined from the hectic level of 1988, capital expenditures abroad by U.S. chemical companies continue to rise. A Department of Commerce survey shows that overseas affiliates of U.S. chemical producers plan to increase their outlays 17% in 1990 to $6.2 billion, compared with a 13% increase last year over 1988, as U.S. firms' overseas markets and globalization efforts remain strong.

CHEMICAL CAPITAL SPENDING: 1989 was strong year, but increases did not match 1988's

$ Millions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
Air Products	$ 414	$ 409	$ 323	$ 367	$ 392	$ 263	$ 246	$ 347	$ 323	$ 364	$ 246
American Cyanamid	398	374	268	263	203	200	165	171	181	196	235
Cabot[a]	192	170	83	80	184	505	80	152	194	137	98
Chemed	14	15	9	9	7	9	5	4	4	4	6
Crompton & Knowles	13	7	4	4	3	3	2	3	7	10	[illegible]
Dow Chemical	1695	1670	995	890	806	781	630	829	1176	1184	1268
Du Pont[b]	2536	2029	1674	1587	1515	1319	1276	1300	1420	1297	864
Ethyl	119	151	139	134	90	103	85	92	141	156	123
B. F. Goodrich	240	181	143	144	202	153	115	144	205	184	192
W. R. Grace	485	418	243	199	348	380	353	560	657	658	514
Great Lakes Chemical	40	47	35	18	21	29	20	29	47	21	18
Hercules	293	251	205	257	234	218	168	174	167	229	186
Loctite	16	14	15	9	11	6	10	11	13	14	9
Lubrizol	65	55	42	41	40	30	25	52	75	92	51
Monsanto	607	590	505	520	645	614	560	673	668	781	566
Nalco Chemical	86	62	57	64	60	53	41	56	59	35	39
Olin	142	147	115	128	154	165	123	129	186	172	161
PPG Industries	537	410	426	356	452	315	450	452	376	401	252
Petrolite	19	20	19	25	24	11	9	24	15	17	12
Quaker Chemical	8	5	4	5	6	4	2	2	1	5	3
Quantum Chemical	583	334	154	102	76	116	71	66	44	49	58
Rohm & Haas	385	338	222	179	159	124	72	126	182	93	68
Stepan	34	20	26	14	19	12	10	16	12	9	14
Union Carbide	785	671	502	524	649	670	761	1179	1186	1129	831
Witco	70	72	69	60	76	85	55	54	83	73	49
TOTAL	$9803	$8460	$6277	$5979	$6376	$6168	$5334	$6645	$7422	$7310	$5871
ANNUAL CHANGE	16%	35%	5%	−6%	3%	16%	−20%	−10%	2%	25%	19%

Note: Figures are for worldwide spending on construction, equipment, and land in consolidated businesses. Where possible, acquisition costs and investments in nonconsolidated businesses are excluded. a Includes acquisitions and investments. b Excludes Conoco. **Source:** Company data

2 Finances of the U.S. Chemical Industry

SHIPMENTS: Strong rise for drugs and related products boosts overall chemical total

$ Billions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
All manufacturing industries	$2781.6	$2611.6	$2390.0	$2260.3	2279.1	$2254.4	$2054.9	$1960.2	$2017.5	$1852.7	$1727.2	7%	5%
Chemicals and allied products	255.6	240.5	212.7	197.1	197.3	198.2	183.2	170.7	180.5	162.5	147.7	6	6
Industrial chemicals[a]	68.9	67.8	59.5	54.1	59.6	61.5	56.6	53.2	62.7	57.3	52.3	2	3
Drugs, soap, and toiletries	82.0	73.1	67.1	65.8	60.9	57.5	54.4	50.7	46.9	41.9	36.7	12	8
Petroleum and coal products	138.4	124.2	124.5	124.9	179.1	189.0	192.6	208.9	224.1	198.7	148.4	11	−1
Rubber and plastic products	95.8	91.1	80.5	73.4	71.3	69.5	60.3	55.4	53.2	47.3	46.8	5	7
Paper and allied products	130.4	124.2	110.3	97.9	93.4	94.8	84.6	79.9	80.2	72.8	65.2	5	7

[a] Excluding pigments. **Source:** Department of Commerce

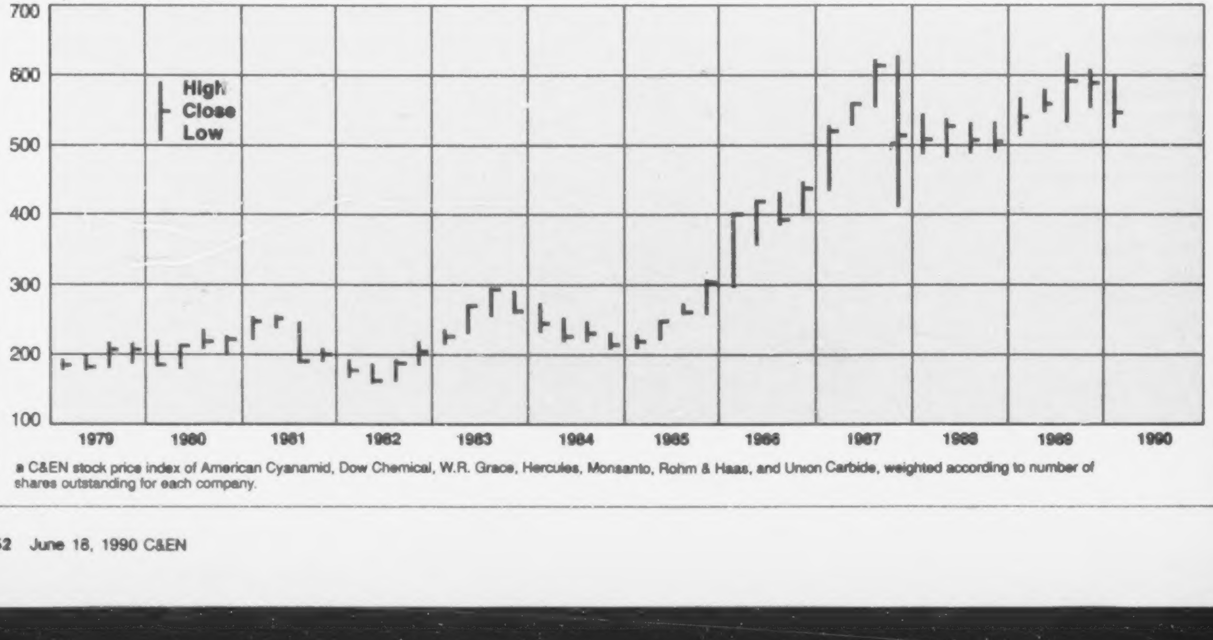
PRICES: Most chemical products outpaced other commodities last year

Producer price indexes, 1982 = 100	Annual average 1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
All commodities	112.2	106.9	102.8	100.2	103.1	103.7	101.3	100.0	98.0	89.8	78.7	5%	4%
Industrial commodities	111.6	106.3	102.6	99.9	103.7	103.3	101.1	100.0	97.4	88.0	75.7	5	4
Chemicals and allied products	123.1	116.3	106.4	102.5	103.7	102.9	100.2	100.0	98.4	89.1	76.1	6	5
Industrial chemicals	114.8	106.8	95.5	91.5	96.0	96.8	97.3	100.0	103.0	91.9	74.9	7	4
Prepared paint	119.5	112.2	108.1	107.0	105.3	103.7	100.7	100.0	95.0	89.5	77.8	6	4
Paint materials	129.1	115.7	107.3	104.4	109.5	108.2	100.3	100.0	98.5	89.9	79.2	12	5
Drugs and pharmaceuticals	160.0	148.4	139.1	129.9	122.2	114.2	107.7	100.0	92.1	83.1	75.9	8	8
Fats and oils, inedible	95.5	110.9	92.7	80.5	110.6	139.1	106.2	100.0	110.7	111.6	141.1	−14	−4
Agricultural chemicals and chemical products	108.7	104.5	96.4	94.2	96.2	97.4	96.0	100.0	97.5	87.9	73.3	4	4
Plastic resins and materials	133.4	132.4	110.3	104.4	107.5	108.9	102.4	100.0	102.0	98.5	83.2	1	5
Other chemicals and allied products	117.3	111.9	107.0	105.8	105.2	102.7	101.3	100.0	94.1	83.1	71.0	5	5
Rubber and plastic products	112.6	109.3	103.0	101.9	101.9	102.2	100.8	100.0	96.4	90.1	80.5	3	3

Source: Department of Labor

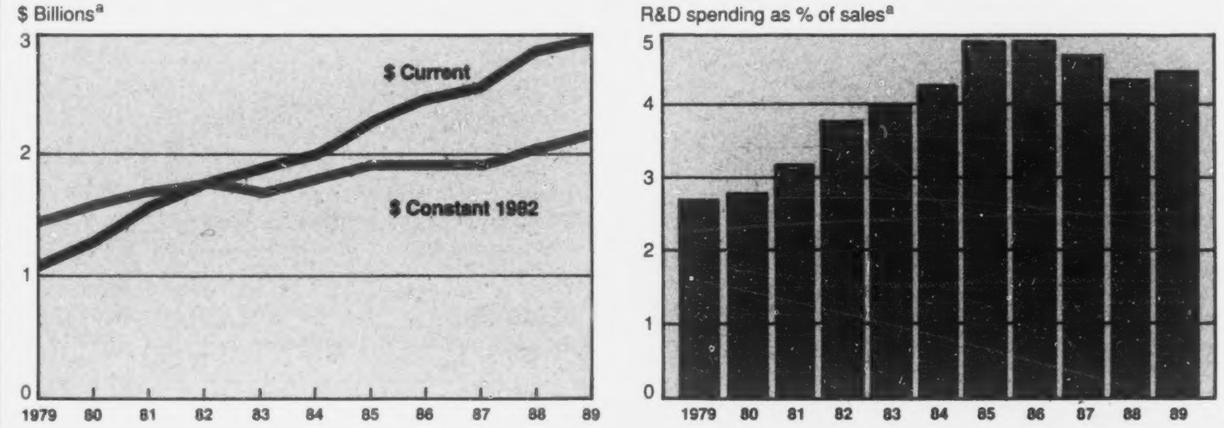
Chemical shares hover a bit below last fall's peak

Stock price index, 1954 = 100[a]



[a] C&EN stock price index of American Cyanamid, Dow Chemical, W.R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide, weighted according to number of shares outstanding for each company.

Growth continues but chemical firms' R&D outlays are little changed relative to sales



a R&D spending by 15 major chemical producers. **Sources:** Company data, Battelle Columbus Laboratories

R&D SPENDING: Companies' budgets up relatively modestly in 1989

$ Millions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
CHEMICAL COMPANIES											
Air Products[a]	$ 71	$ 72	$ 57	$ 61	$ 51	$ 44	$ 40	$ 37	$ 32	$ 30	$ 24
American Cyanamid	406	365	314	278	251	232	208	185	166	148	130
Dow Chemical	873	772	670	605	547	507	492	460	404	314	269
Ethyl	61[b]	59[b]	50	47	47	40	39	39	37	34	29
W. R. Grace	125	119	107	94	92	81	73	64	57	45	42
Hercules	79	74	74	71	76	72	74	74	65	57	50
International Flavors	52	50	45	39	34	32	32	31	30	29	27
Lubrizol	70	65	62	51	44	33	37	36	33	28	23
Monsanto	598	648	615	596	470	370	290	264	233	208	161
Nalco	41	37	35	33	32	32	30	33	30	28	21
Olin	66	58	62	56	53	52	49	45	38	31	26
Petrolite	12	12	12	12	12	12	13	10	8	7	6
PPG Industries	233	227	227	204	176	150	127	127	119	103	83
Rohm & Haas	175	156	142	133	124	109	100	92	77	67	54
Union Carbide	181	159	159	148	275	265	245	240	207	166	161
TOTAL	$3043	$2867	$2631	$2428	$2284	$2031	$1849	$1737	$1536	$1295	$1106
ANNUAL CHANGE	**6%**	**9%**	**8%**	**6%**	**12%**	**10%**	**6%**	**13%**	**19%**	**17%**	**14%**
PHARMACEUTICAL & DIVERSIFIED COMPANIES											
Allied-Signal[c]	$ 603	$ 647	$ 667	$ 734	$ 470	$ 389	$ 383	$ 177	$ 152	$ 105	$ 70
Du Pont	1387	1319	1223	1156	1144	1097	966	879	718	591	509
Eastman Kodak	1253	1147	992	1059	976	838	746	710	615	520	459
Eli Lilly	605	512	466	427	370	341	294	267	235	201	178
FMC	150	144	132	146	149	121	102	105	94	81	69
Merck & Co.	751	669	566	480	426	393	356	320	274	234	188
Morton International[c,d]	38	35	31	29	34	28	21	7	6	6	5
Pfizer	531	473	401	336	287	255	230	199	179	162	139
Upjohn	407	380	356	314	284	247	218	185	162	139	122
TOTAL	$5725	$5326	$4834	$4681	$4140	$3709	$3316	$2849	$2435	$2039	$1739
ANNUAL CHANGE	**7%**	**10%**	**3%**	**13%**	**12%**	**12%**	**16%**	**17%**	**19%**	**17%**	**16%**

Note: Prior years not restated to reflect company revisions. a For fiscal year ending Sept. 30. b Adjusted to reflect spin-off of Tredegar Industries. c Includes all company-financed R&D but excludes contract R&D. d Fiscal year ends June 30; data for Morton International prior to 1985. **Source:** Company data

INDUSTRY BALANCE SHEET: Stockholders' equity up 10% as liabilities hold steady

Industrial chemicals and synthetics

Assets	1989	1988	Change
	($ billions)		
Current assets			
Cash	$ 1.70	$ 2.16	−21%
Short-term securities	1.42	1.96	−27
Receivables	17.62	17.41	1
Inventories	14.66	14.59	1
Other current assets	3.97	4.71	−16
Total	**39.37**	**40.82**	**−4**
Fixed assets			
Depreciable fixed assets	**93.72**	**68.51**	**6**
Land and mineral rights	5.52	5.46	1
Less: accumulated depreciation and depletion	48.30	46.24	4
Net fixed assets	50.93	47.73	7
Other assets, including investments and intangibles	**37.60**	**34.42**	**9**
TOTAL ASSETS	**$127.91**	**$122.97**	**4%**

Source: Bureau of the Census

Liabilities and stockholders' equity	1989	1988	Change
	($ billions)		
Current liabilities			
Short-term debt	$ 4.88	$ 4.39	11%
Accounts payable	9.10	8.39	8
Accrued income taxes	1.29	1.71	−25
Current portion of long-term debt	1.93	1.77	9
Other current liabilities	10.60	12.05	−12
Total	**27.80**	**28.32**	**−2**
Long-term debt	**29.42**	**28.51**	**3**
Other liabilities, including deferred taxes and minority interest	**14.10**	**14.47**	**−3**
TOTAL LIABILITIES	**71.32**	**71.30**	**0**
Stockholders' equity			
Capital stock and other capital	17.78	18.05	−1
Retained earnings	38.81	33.62	15
TOTAL STOCKHOLDERS' EQUITY	**56.59**	**51.67**	**10**
TOTAL LIABILITIES AND STOCKHOLDERS' EQUITY	**$127.91**	**$122.97**	**4%**

DEBT RATIOS: Remain high compared with levels of early 1980s

$ Billions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
INDUSTRIAL CHEMICALS AND SYNTHETICS											
Long-term debt	$ 29.4	$ 28.5	$ 28.3	$ 20.8	$ 19.2	$ 18.1	$ 19.4	$ 22.0	$ 21.4	$ 16.8	$ 14.8
Stockholders' equity	$ 56.6	$ 51.7	$ 45.3	$ 41.6	$ 40.8	$ 46.5	$ 45.3	$ 45.9	$ 42.5	$ 39.8	$ 32.3
Debt ratio[a]	34.2%	35.6%	38.4%	33.4%	32.0%	28.0%	30.0%	32.4%	33.5%	29.6%	31.4%
CHEMICALS AND ALLIED PRODUCTS											
Long-term debt	$ 64.2	$ 58.9	$ 53.6	$ 46.8	$ 38.2	$ 33.8	$ 36.2	$ 38.2	$ 36.9	$ 28.3	$ 24.9
Stockholders' equity	$ 127.1	$120.5	$106.9	$100.8	$100.3	$100.3	$ 97.2	$ 95.3	$ 89.9	$ 79.5	$ 67.4
Debt ratio[a]	33.5%	32.8%	33.4%	31.7%	27.6%	25.2%	27.2%	28.6%	29.1%	26.3%	27.0%
ALL MANUFACTURING											
Long-term debt	$ 594.9	$535.4	$451.7	$407.5	$367.0	$324.2	$286.6	$293.1	$266.5	$236.2	$204.[illegible]
Stockholders' equity	$1006.3	$979.9	$912.8	$878.1	$870.7	$883.6	$837.6	$783.0	$762.3	$699.7	$624.0
Debt ratio[a]	37.2%	35.3%	33.1%	31.7%	29.6%	26.8%	25.5%	27.2%	25.9%	25.2%	24.7%

Note: Because of the changes in accounting rules and industry classifications, numbers over the entire range of years are not strictly comparable. [a] Long-term debt as a percentage of long-term debt plus stockholders' equity. **Source:** Bureau of Census

CASH FLOW: Chemical firms hiked borrowing and used working capital to meet cash needs last year

$ Millions, % of total	1989		1988		1987		1986		1985	
SOURCES OF FUNDS										
Net income	$ 7,621	29.2%	$ 7,698	39.2%	$ 5,749	29.8%	$ 3,395	13.4%	$ 658	4.3%
Depreciation and depletion	6,108	23.4	5,602	28.6	5.311	27.6	5,157	20.3	5,079	32.9
Deferred taxes	156	0.6	302	1.5	304	1.6	555	2.2	−37	−0.2
Other internal sources	3,355	12.8	2,164	11.0	4,257	22.1	6,378	25.1	7,109	46.1
Long-term debt	8,125	31.1	3,619	18.4	2,893	15.0	8,732	34.4	2,339	15.2
Stock	753	2.9	236	1.2	759	3.9	1,199	4.7	265	1.7
TOTAL	**$ 26,118**	**100.0%**	**$19,622**	**100.0%**	**$19,273**	**100.0%**	**$25,416**	**100.0%**	**$15,414**	**100.0%**
APPLICATIONS OF FUNDS										
Dividends	$ 2,602	10.0%	$ 2,308	11.8%	$ 2,196	11.4%	$ 1,994	7.8%	$ 2,050	13.3%
Capital expenditures	10,017	38.4	9,125	46.5	6,525	33.9	6,076	23.9	6,612	42.9
Additions to working capital	−1,714	−6.6	756	3.9	2,868	14.9	−437	−1.7	−47	−0.3
Reduction of long-term debt	5,529	21.2	3,107	15.8	2,649	13.7	7,801	30.7	2,672	17.3
Other applications	9,685	37.1	4,326	22.0	5,035	26.1	9,982	39.3	4,126	26.8
TOTAL	**$ 26,118**	**100.0%**	**$19,622**	**100.0%**	**$19,273**	**100.0%**	**$25,416**	**100.0%**	**$15,414**	**100.0%**

Note: Data are totals for 12 major chemical producers: American Cyanamid, Dow Chemical, Du Pont, Ethyl (excludes insurance business), B. F. Goodrich, W. R. Grace, Hercules, Monsanto, Olin, Quantum Chemical, Rohm & Haas, and Union Carbide. **Sources:** Company annual reports

2 Finances of the U.S. Chemical Industry

Last year was a good one for many leading chemical producers at the same time that it was distinctly mediocre for several others. The difference often reflected the type of products that a company turns out.

Firms with a product line focused on specialty chemicals frequently managed to push sales and earnings to record highs despite a slowing in the nation's economic growth overall. Great Lakes Chemical, for example, with a broad line of specialties based on bromine or furfural, upped its net income 19%, thanks in part to developing new market niches for its products. Loctite, finding new outlets for its adhesives, lifted profits 30%. Some of the chemical industry's highly diversified giants, such as Dow, Du Pont, and Monsanto, also did relatively well. For them, too, newly developed specialty products get much of the credit.

On the other hand, for producers who are tied closely to commodity petrochemicals or plastics and consequently are often less able to exert as much control over their competitive markets and vulnerable selling prices—among them Quantum Chemical, Sterling Chemicals, Borden Chemicals & Plastics, and B. F. Goodrich—profitability last year often was disappointing compared with 1988's robust results.

Explanation of table headings

Year. Data are for calendar year unless otherwise indicated.

Net sales. Gross sales, less discounts, allowances, and returns; generally excludes excise taxes and other operating income or revenues.

Net income. Net sales and other income, less operating costs, nonoperating charges, depreciation, depletion, interest expense, deferred charges, minority interest in income, and taxes. Nonrecurring or extraordinary credits and charges have been excluded in most cases, but these items are indicated by a footnote.

Total assets. Sum at year's end of current assets, investments, prepaid expenses, net plant and equipment, and other tangible assets. Excludes insofar as possible intangible assets including goodwill, value of patents and trademarks, and the like.

Current ratio. The ratio of current assets (cash, marketable securities, receivables, and inventories but excluding prepaid expenses) to total current liabilities.

Net plant and equipment. Value at year's end of fixed assets, less accumulated depreciation, amortization, and depletion.

Capital expenditures. Total spending during the year for new fixed assets, such as plant, equipment, and land, and for replacement and modernization of facilities.

Net worth. Equity at year's end of preferred and common stock holders, including value of capital stock, capital and earned surplus, and surplus reserves, as well as contingency and miscellaneous reserves for which no definite purpose is stated. Intangible assets are deducted insofar as possible.

Net income (breakdown). Percent of sales: net income divided by net sales. **Percent of net worth:** net income divided by tangible net worth. **Dollars per share:** net income, less preferred dividends, divided by the number of shares of common stock outstanding. All figures are adjusted for stock splits, but no adjustment has been made for earlier years as a result of stock dividends or for dilution that might result from the conversion of preferred stock or debt to common stock or the exercise of stock options outstanding.

Dividends per share. Cash dividends paid (or declared) on each share of common stock; excludes the value of stock dividends, which are indicated by a footnote.

Dividend yield. Dividends per share divided by the average of the high and low prices of the common stock during the calendar year.

Stock price range. High-low market prices of common stock during the calendar year, adjusted for stock splits but not for stock dividends.

Price-earnings ratio. Average of the high and low prices of the common stock during the calendar year divided by net income per share.

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
(Money figures in thousands of dollars unless otherwice indicated)														
CHEMICALS														
Air Products & Chemicals														
1989[a]	$2,641,823	$222,137	$3,313,343	1.3	$2,217,594	$413,735	$1,392,534	8.4%	16.0%	$4.04	$1.26	2.8%	$48¾–40	11.0
1988[a]	2,431,866	213,747	2,962,295	1.1	2,061,642	409,433	1,235,027	8.8	17.3	3.90	1.10	2.4	53⅜–36½	11.5
1987[a]	2,132,176	159,688[b]	2,695,625	1.2	1,920,520	322,765	1,140,512	7.5	14.0	2.83[b]	0.90	2.2	53⅞–29	14.6
1986	1,982,134	4,735[c]	2,700,151	1.4	1,829,122	366,563	1,094,562	0.2	0.4	0.08[c]	0.77	2.2	41⅝–29⅛	422.2
American Cyanamid Co.														
1989	$4,825,000	$292,000	$4,719,800	1.4	$1,757,000	$397,600	$2,070,000	6.1%	14.1%	$3.12	$1.31	2.5%	$60⅜–45⅝	17.0
1988	4,592,000	305,600	4,332,200	1.4	1,556,800	373,800	1,801,100	6.7	17.0	3.41	1.16	2.4	56–41⅞	14.4
1987	4,166,100	264,000[d]	3,878,400	1.5	1,391,900	268,100	1,622,400	6.3	16.3	2.89	1.025	2.4	57–29	14.9
1986	3,815,900	202,500	3,482,400	1.7	1,267,700	262,500	1,536,000	5.3	13.2	2.18	0.95	2.6	44⅞–27⅛	16.5
Arco Chemical Co.														
1989	$2,663,000	$405,000	$2,655,000	2.0	$1,263,000	$262,000	$1,591,000	15.5%	25.5%	$4.22	$2.125	6.1%	$40⅜–28¾	8.2
1988	2,700,000	494,000	2,548,000	1.8	1,078,000	199,000	1,375,000	18.3	35.9	5.00	0.85	2.8	38–23¼	6.1
1987[e]	1,952,000	257,000	2,534,000	1.3	984,000	295,000	1,116,000	13.2	23.0	2.58[f]	0.20	0.7	38¾–17	10.8
1986	1,541,000	143,000	1,450,000	2.6	752,000	167,000	952,000[f]	9.3	15.0	1.44[f]	—	—	—	—
Betz Laboratories														
1989	$ 516,669	$ 55,860	$ 358,743	2.4	$ 201,464	$ 52,952	$ 172,971	10.8%	32.3%	$3.53	$1.78	3.2%	$62⅜–47¼	15.5
1988	447,580	48,385	307,862	1.9	174,970	43,505	219,901	10.8	22.0	3.15	1.60	3.4	52½–41¼	14.9
1987	385,868	40,634	275,664	1.7	153,200	25,428	193,959	10.5	20.9	2.59	1.46	3.1	58¼–35	18.0
1986	344,377	35,544	267,681	2.3	144,053	22,750	202,104	10.3	17.6	2.23	1.36	3.4	44¾–35	17.9

a Fiscal year ends Sept. 30. b Excludes extraordinary net loss on extinguishment of debt of $4.1 million ($0.07 per share). c Includes special charge for writedown of assets, revaluation of South African investment, and staff reduction program of $132.2 million ($2.25 per share) and for loss of investment tax credits of $7 million ($0.13 per share). d From continuing operations; excludes net income from discontinued operations of $11.6 million ($0.13 per share) but includes gain on sale of fragrance and skin care business, before taxes, of $12.0 million ($0.13 per share). Arco Chemical, previously a subsidiary of Atlantic Richfield Co., became an independent, publicly owned company on Oct. 5, 1987. f Pro forma.

2 Finances of the U.S. Chemical Industry

(Money figures in thousands of dollars unless otherwise indicated)

								NET INCOME						
Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	% of sales	% of net worth	$ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
Borden Chemicals & Plastics Ltd. Partnership														
1989	$ 465,923	$ 69,495	$ 549,628	1.9	$ 417,186	$ 28,157	$ 341,707	14.9%	20.3%	$ 1.87[a]	$2.45[a]	14.4%	$ 24–10[a]	9.1
1988	552,975	121,014	604,822	1.7	429,280	18,877	363,271	21.9	33.3	3.26[a]	3.02[a]	19.5	20⅛–10⅞	4.8
1987[b]	35,894	4,781	560,319	1.7	449,258	3,485	354,534	13.3	—	0.13[a]	0.11[a]	1.0	12–9¾[a]	83.7
1986	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cabot Corp.														
1989[c]	$ 1,936,912	($6,509)[d,e]	$1,400,550	1.3	$ 743,179	$ 192,302	$ 472,333	—	—	($ 0.40)[d,e]	$1.01	2.6%	$45⅛–32⅞	—
1988[c]	1,676,588	61,175[f]	1,530,186	1.3	838,909	169,957	594,295	3.6%	10.3%	2.27[f]	0.92	3.2	41¾–29⅛	15.6
1987[c]	1,424,041	39,235[g]	1,447,001	1.2	794,470	81,087	574,610	2.8	6.8	1.42[g]	0.92	2.5	49¼–25¼	26.2
1986[c]	1,309,915	73,061[h]	1,490,759	2.0	642,137	72,551	572,145	5.6	12.8	2.56[h]	0.92	3.1	35⅜–23⅜	11.5
Chemed Corp.														
1989	$ 591,824	$26,182	$ 279,181	1.6	$ 65,814	$ 14,116	$ 64,634	4.4%	40.5%	$ 2.61	$1.84	5.2%	$38⅝–32½	13.6
1988	500,647	20,649[i]	268,496	1.7	61,102	14,641	57,061	4.1	36.2	2.23[i]	1.72	5.1	38–29¾	15.2
1987	391,004	20,362	220,549	1.5	48,545	8,893	69,944	5.2	29.1	2.28	1.60	4.5	44⅛–26⅜	15.5
1986	359,476	6,830[j]	229,316	1.6	46,554	9,385	75,339	1.9	9.1	0.76[j]	1.56	4.4	40–30⅛	46.1
Crompton & Knowles Corp.														
1989	$ 355,817	$24,501	$ 189,952	1.6	$ 50,847	$ 13,407	$ 71,003	6.9%	34.5%	$ 2.00	$0.58	2.5%	$31½–14⅞	11.6
1988	289,787	16,845[k]	177,204	1.5	43,685	7,050	53,483	5.8	31.5	1.43[k]	0.43	3.1	17⅞–10	9.8
1987	237,469	11,750	127,689	2.2	29,085	3,632	68,265	4.9	17.2	0.98	0.335	2.8	15⅛–9	12.4
1986	213,242	8,923[l]	126,881	2.2	28,511	3,514	60,565	4.2	14.5	0.66[l]	0.315	4.0	9⅞–6⅛	12.0
Dexter Corp.														
1989	$ 848,724	$42,977	$ 611,277	2.2	$ 252,895	$ 33,119	$ 242,068	5.1%	17.8%	$ 1.73	$0.82	3.0%	$34¾–20⅛	15.9
1988	827,266	39,889[m]	540,960	2.2	186,894	26,145	221,795	4.8	18.0	1.61[m]	0.80	3.3	28¾–20¼	15.2
1987	782,781	42,785	517,296	2.3	183,972	23,619	205,269	5.5	20.8	1.72	0.60	2.4	32⅜–17	14.4
1986	650,051	33,635	475,337	2.0	174,644	23,861	168,309	5.2	20.0	1.35	0.57	2.8	23⅜–16⅞	14.9
Dow Chemical Co.														
1989	$17,600,000	$2,487,000	$18,169,000	1.1	$ 7,642,000	$1,764,000	$ 3,960,000	14.1%	62.8%	$ 9.20	$2.18	3.4%	$72¼–55½	6.9
1988	16,682,000	2,410,000[n]	15,548,000	1.9	6,576,000	1,267,000	6,564,000	14.4	36.7	8.55[n]	1.63	2.9	62⅝–51⅛	6.7
1987	13,377,000	1,245,000[o]	13,871,000	1.7	5,551,000	995,000	5,284,000	9.3	23.6	4.33[o]	1.40	2.5	73–39⅛	13.0
1986	11,113,000	741,000[p]	11,939,000	1.6	5,347,000	890,000	4,865,000	6.7	15.2	2.58[p]	1.23	3.6	41⅛–26⅝	13.1
E. I. du Pont de Nemours & Co.														
1989	$35,534,000	$2,480,000	$33,829,000	1.2	$18,876,000	$4,285,000	$14,912,000	7.0%	16.6%	$ 3.53	$1.45	4.1%	$42⅛–28⅝	10.0
1988	32,917,000	2,190,000	30,159,000	1.5	17,221,000	4,001,000	15,020,000	6.7	14.6	3.04	1.23	4.4	30⅞–25¼	9.3
1987	30,468,000	1,786,000	27,604,000	1.5	15,854,000	3,035,000	13,639,000	5.9	13.1	2.46	1.10	3.2	43⅝–25	13.9
1986	27,148,000	1,538,000	26,083,000	1.5	15.697,000	2,737,000	12,724,000	5.7	12.1	2.12	1.02	4.0	30¾–19⅞	12.0
Ethyl Corp.														
1989	$1,519,637[q]	$219,468[r]	$ 5,507,009[s]	2.2	$ 579,760	$ 119,082	$ 776,785	14.4%	28.3%	$ 1.83[r]	$0.51	2.0%	$29–21⅛	13.7
1988	2,011,487[q]	231,016	5,107,817[s]	2.5	719,551	151,116	986,289	11.5	23.4	1.91	0.45	2.2	24⅛–17¼	10.8
1987	1,720,338[q]	193,319	1,875,614	2.2	674,075	138,481	852,799	11.2	22.7	1.57	0.40	1.7	32¼–15	15.0
1986	1,579,254[q]	177,734	1,667,825	2.1	594,238	133,700	895,790	11.3	19.8	1.40	0.335	1.8	22¾–13½	12.9
Ferro Corp.														
1989	$ 1,083,573	$49,748	$ 655,206	1.8	$ 220,022	$ 49,581	$ 283,144	4.6%	17.6%	$ 2.25	$0.60	1.9%	$40–22¼	13.8
1988	1,008,990	46,620	574,943	1.7	197,222	49,308	282,137	4.6	16.5	2.26	0.46	2.3	27⅛–14	9.1
1987	871,088	31,687	521,314	1.7	171,889	30,674	249,039	3.6	12.7	1.53	0.45	2.7	20⅞–11⅝	10.6
1986	725,241	24,082	443,801	1.9	153,712	23,162	217,750	3.3	11.1	1.18	0.40	3.4	13¾–10	10.1
First Mississippi Corp.														
1989[t]	$ 433,469	$16,511	$ 472,394	1.6	$ 280,008	$ 107,011	$ 187,145	3.8%	8.8%	$ 0.81	$0.285	1.7%	$20½–13⅛	20.8
1988[t]	318,086	32,475	325,339	1.5	166,966	60,381	181,447	10.2	17.9	1.61	0.24	1.6	18⅜–12	9.4
1987[t]	278,946	18,610	276,638	1.8	152,671	19,527	138,882	6.7	13.4	0.93	0.24	1.9	19⅛–6½	13.8
1986[t]	268,898	(28,110)[d]	287,562	1.6	155,266	31,635	125,521	—	—	(1.42)[d]	0.24	3.6	8⅛–5¼	—
Georgia Gulf Corp.														
1989	$ 1,104,468	$191,990	$ 448,476	2.2	$ 209,080	$ 54,159	$ 305,828	17.4%	62.8%	$ 7.58	$1.00	2.1%	$59⅞–36	6.3
1988	1,060,612	193,604	437,083	2.0	169,256	25,062	235,839	18.3	82.1	6.75	0.65	2.0	39⅞–24⅜	4.8
1987	707,453	91,736[u]	308,609	1.7	119,984	9,931	142,546	13.0	64.4	3.15[u]	0.20	0.9	34½–9⅞	7.1
1986	583,255	39,123	264,632	2.0	119,116	7,428	77,956	6.7	50.2	1.20	0.00	0.0	10–9¾	8.2

a Per partnership preference unit. b Borden Chemicals & Plastics, previously the basic chemicals and polyvinyl chloride operations of Borden Inc., commenced independent operations as a publicly owned limited partnership Nov. 30, 1987. c Fiscal year ends Sept. 30. d Net loss. e From continuing operations; includes pretax loss on restructuring of energy group of $71.7 million but excludes net gain from sale of discontinued operations of $24.6 million ($0.95 per share). f Excludes extraordinary net charge on early retirement of debt of $816,000 ($0.03 per share). g Excludes extraordinary net charge on early retirement of debt of $10.5 million ($0.38 per share). h Excludes extraordinary net charge on early retirement of debt of $2.0 million ($0.07 per share). i From continuing operations; excludes net income from discontinued operations, extraordinary net gain on termination of pension plan, and cumulative effect of changes in accounting principles of $3.5 million ($0.37 per share). j From continuing operations; excludes net income and net gain on sale of discontinued Vestal Laboratories operations of $30.0 million ($3.36 per share) and extraordinary net gain on termination of pension plan of $811,000 ($0.09 per share). k From continuing operations; excludes net loss from operations and disposal of maintenance chemicals business of $1.5 million ($0.12 per share). l From continuing operations; excludes net income and net charge for discontinued Kem operations of $7.9 million ($0.62 per share). m From continuing oeprations; excludes net loss from discontinued operations of $4.4 million ($0.18 per share). n Excludes net loss on early extinguishment of debt of $12 million ($0.04 per share). o Excludes net loss on early extinguishment of debt of $5 million ($0.02 per share). p Excludes net loss on early extinguishment of debt of $9 million ($0.03 per share). q Excludes insurance revenues. r From continuing operations; excludes income from spun-off aluminum, plastics, and energy businesses of $11.9 million ($0.10 per share). s Includes total assets of insurance business, previously carried as net investment in the business. t Fiscal year ends June 30. u Excludes net charge on retirement of debt of $9.9 million ($0.34 per share).

(Money figures in thousands of dollars unless otherwise indicated)

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
								% of sales	% of net worth	$ per share				
B. F. Goodrich Co.														
1989	$2,419,700	$171,200[a]	$2,102,900	2.0	$ 991,500	$240,400	$1,117,000	7.1%	15.3%	$ 6.23[a]	$2.00	3.7%	$69–38½	8.6
1988	2,416,700	209,900[b]	1,987,300	1.9	934,400	180,500	1,080,200	8.7	19.4	7.99[b]	1.72	3.5	60¾–37½	6.1
1987	2,168,000	83,900[c]	1,905,800	1.4	898,200	142,600	972,600	3.9	8.6	3.17[c]	1.56	3.4	65–27¾	14.6
1986	2,553,300	12,900[d]	1,786,700	1.4	865,200	144,000	799,200	0.5	1.6	0.46[d]	1.56	3.9	47⅞–32⅛	87.0
W. R. Grace & Co.														
1989	$6,114,600	$256,600[e]	$5,321,300	1.3	$2,220,000	$484,600	$1,432,600	4.2%	17.9%	$ 3.01[e]	$1.40	4.4%	$39⅛–25⅛	10.7
1988	5,786,100	192,000[f]	5,095,200	1.3	2,028,300	418,100	1,336,000	3.3	14.4	2.26[f]	1.40	5.2	29⅞–23½	11.8
1987	4,515,400	141,900[g]	4,361,500	1.4	1,701,000	242,500	1,351,200	3.1	10.5	1.67[g]	1.40	5.0	37⅜–19⅛	16.9
1986	3,725,700	(375,400)[h,i]	3,993,000	1.3	1,579,000	199,100	1,204,400	—	—	(4.47)[h,i]	1.40	5.3	30⅜–22⅝	—
Great Lakes Chemical Corp.														
1989	$ 792,327	$122,918	$ 934,802	2.0	$ 275,864	$ 40,466	$ 428,263	15.5%	28.7%	$ 3.52	$0.38	1.0%	$48–28⅛	10.8
1988	557,770	103,288	612,242	1.7	234,405	47,017	430,629	18.5	24.0	2.97	0.34	1.2	33–24¼	9.7
1987	478,386	55,536	523,365	1.8	218,403	35,186	338,880	11.6	16.4	1.67	0.30	1.1	38½–18	16.9
1986	300,329	26,817	447,840	2.3	209,425	18,327	172,538	8.9	15.5	0.89	0.26	1.4	22¼–15½	21.1
Hercules														
1989	$3,091,669	($96,359)[h,j]	$3,653,163	1.7	$1,416,475	$292,554	$1,897,206	—	—	($ 2.09)[h,j]	$2.24	4.9%	$52¼–38⅜	—
1988	2,802,072	120,435	3,325,294	2.8	1,164,102	251,043	2,044,533	4.3%	5.9%	2.55	2.00	4.1	54–42⅝	18.9
1987	2,693,003	208,000[k]	3,492,077	3.6	1,075,389	205,037	2,189,867	7.7	9.5	4.02[k]	1.84	3.2	73½–40	14.1
1986	2,615,110	206,200[l]	2,914,319	2.6	1,152,141	256,913	1,703,151	7.8	12.1	3.66[l]	1.72	3.5	60–37	13.3
IMC Fertilizer Group														
1989[m]	$1,221,700	$137,300	$1,677,900	1.4	$1,144,100	$ 55,300	$ 765,300	11.2%	17.9%	$ 5.27	$1.02	2.5%	$49¾–31¼	7.7
1988[m,n]	1,085,600	111,700	1,472,100	1.6	780,000	26,300	676,100	10.3	16.5	3.88	0.37	1.1	45⅛–22½	8.7
1987[m]	876,200	26,600	1,332,200	1.7	841,600	110,400	1,004,300	3.0	2.6	0.10	—	—	—	—
1986[m]	866,000	(34,700)[h]	1,242,500	2.2	—	52,000	1,028,800	—	—	—	—	—	—	—
International Flavors & Fragrances														
1989	$ 869,519	$138,565	$ 969,649	5.1	$ 236,505	$ 34,178	$ 764,913	15.9%	18.1%	$ 3.65	$1.92	3.0%	$77½–48½	17.3
1988	839,545	128,684	882,333	5.0	228,152	40,812	695,433	15.3	18.5	3.40	1.60	3.3	54½–43⅛	14.4
1987	745,861	107,017	874,554	4.2	219,305	36,946	659,908	14.3	16.2	2.83	1.24	2.6	57¾–37¼	16.8
1986	620,679	85,683	672,616	4.6	186,891	26,771	521,475	13.8	16.4	2.29	1.16	2.8	48⅞–34½	18.2
International Minerals & Chemical Corp.														
1989[m]	$ 982,900	$110,300[o]	$1,753,000	3.2	$ 480,200	$ 82,200	$ 669,600	11.2%	16.5%	$ 4.20[o]	$1.00	2.1%	$55½–38	11.1
1988[m]	1,470,600	103,900[p]	1,588,900	2.0	445,800	81,200	822,800	7.1	12.6	3.30[p]	1.00	2.3	51½–37¼	13.4
1987[m]	1,637,500	14,600[q]	2,242,400	1.4	2,292,500	62,500	877,200	0.9	1.7	0.08[q]	1.00	2.5	53–26½	496.9
1986[m]	1,177,700	(79,600)[h,r]	2,225,200	2.2	2,170,700	93,900	792,400	—	—	(2.96)[h,r]	1.80	5.9	36¼–25	—
Lawter International														
1989	$ 136,006	$19,468	$ 133,988	3.9	$ 24,412	$ 3,073	$ 87,752	14.3%	22.2%	$ 0.81	$0.52	4.1%	$13⅞–11⅜	15.6
1988	125,818	20,851	125,210	3.7	24,546	4,524	79,521	16.6	26.2	0.88	0.52	4.2	14⅛–10¾	14.1
1987	112,018	16,701	109,917	4.3	22,603	1,528	69,458	14.9	24.0	0.71	0.42	3.5	15⅝–8½	17.0
1986	103,515	12,945	93,392	3.7	22,447	1,613	55,191	12.5	23.5	0.56	0.42	3.9	13–8⅝	19.5
Loctite Corp.														
1989[m]	$ 456,498	$54,476	$ 344,206	2.8	$ 70,143	$ 15,983	$ 211,805	11.9%	25.7%	$ 3.03	$0.90	2.1%	$51–32¾	13.8
1988[m]	416,880	41,850	328,833	2.4	73,008	14,466	187,100	10.0	22.4	2.32	0.61	1.8	39–27	14.2
1987[m]	337,802	30,655	289,367	1.9	70,802	15,470	167,561	9.1	18.3	1.69	0.47	1.7	36–19	16.3
1986[m]	266,788	23,173	240,665	2.2	57,711	9,299	150,163	8.7	15.4	1.28	0.41	2.0	24⅞–16⅝	16.2
Lubrizol Corp.														
1989	$1,220,386	$93,980	$ 960,184	2.9	$ 316,493	$ 64,721	$ 663,264	7.7%	14.2%	$ 2.52	$1.38	3.5%	$45⅛–34⅛	15.7
1988	1,117,493	131,206[s]	970,671	3.0	298,670	54,611	664,308	11.7	19.8	3.40[s]	1.30	3.6	42⅜–30	10.6
1987	1,013,430	81,335	939,378	3.0	297,573	42,040	621,633	8.0	13.1	2.06	1.22	3.6	41¾–25¼	16.3
1986	976,776	78,185	877,907	2.7	289,078	40,460	572,679	8.0	13.7	1.97	1.17	3.9	35⅛–25⅝	15.4
Monsanto Co.														
1989	$8,681,000	$679,000	$6,922,000	1.4	$3,173,000	$607,000	$2,259,000	7.8%	30.1%	$ 5.02	$1.65	3.2%	$62⅛–40¼	10.2
1988	8,293,000	591,000	6,671,100	1.3	3,146,000	590,000	2,010,000	7.1	29.4	4.14	1.475	3.6	46⅛–36¾	10.0
1987	7,639,000	436,000	6,502,000	1.4	3,076,000	505,000	1,948,000	5.7	22.4	2.82	1.375	3.5	50⅛–28½	14.0
1986	6,879,000	433,000	6,125,000	1.4	2,913,000	520,000	1,637,000	6.3	26.5	2.78	1.29	4.1	40¾–22⅜	11.4
Morton International														
1989[m]	$1,406,600	$122,100[t]	$1,169,600	1.7	$ 553,400	$131,900	$ 706,000	8.7%	17.3%	$ 2.55[t]	—	—	$41⅞–31½	14.4
1988[m,u]	2,316,400	159,400[v]	1,670,800	1.8	760,300	163,000	815,900	6.9	19.5	3.33[v]	$0.82	2.0%	46–35⅝	12.3
1987[m,u]	1,987,300	138,000	1,426,400	1.5	655,900	130,400	700,400	6.9	19.7	2.90	0.745	1.7	54¾–31	14.8
1986[m,u]	1,949,900	132,900	1,225,000	1.7	593,900	95,700	629,900	6.8	21.1	2.80	0.685	1.9	42½–30	12.9

a From continuing operations; excludes net income from discontinued operations of $1.2 million ($0.04 per share). **b** From continuing operations; excludes net loss from discontinued operations of $16.9 million ($0.68 per share) and net gain from cumulative effect of change in accounting for income taxes of $2.7 million ($0.11 per share). **c** From continuing operations; excludes net loss from discontinued operations of $4.7 million ($0.20 per share) and extraordinary net income of $25.8 million ($1.09 per share). **d** Excludes extraordinary net income of $19.8 million ($0.86 per share). **e** From continuing operations; excludes net loss from discontinued operations of $3.4 million ($0.04 per share). **f** From continuing operations; excludes net income from discontinued operations and net gain from cumulative effect of accounting change of $41.6 million ($0.49 per share). **g** From continuing operations; excludes net income from discontinued operations of $18.6 million ($0.22 per share) and tax benefit of operating loss carry-forward of $12.6 million ($0.14 per share). **h** Net loss. **i** From continuing operations; includes asset write-downs and reserves, before taxes, of $368.8 million but excludes net loss from discontinued operations of $96.9 million ($1.15 per share). **j** Excludes net gain from cumulative effect of accounting changes of $15.0 million ($0.33 per share). **k** Excludes net gain on disposal of Himont and other net gains and charges of $613.7 million ($10.72 per share). **l** Excludes nonrecurring net gains from sale of investments and businesses and nonrecurring net costs of $20.5 million ($0.36 per share). **m** Fiscal year ends June 30. **n** IMC Fertilizer Group, previously the fertilizer business group of International Minerals & Chemical Corp., became an independent, privately owned company on Feb. 2, 1988. **o** From continuing operations; excludes net gain from discontinued operations of $6.7 million ($0.29 per share). **p** From continuing operations; excludes net loss on disposal of discontinued operations of $5.0 million ($0.19 per share) and extraordinary credit of $16.2 million ($0.55 per share). **q** From continuing operations; excludes net income on disposal of discontinued operations of $11.3 million ($0.41 per share) and extraordinary net charge of $4.8 million ($0.18 per share). **r** From continuing operations; excludes net loss from and provision for loss on disposal of discontinued gas and oil and industrial products operations of $137.4 million ($5.08 per share). **s** Includes credit for patent litigation settlement, before taxes, of $81.2 million but excludes net credit for cumulative effect of change in accounting for income taxes of $8.8 million ($0.22 per share). **t** Excludes extraordinary net charges related to separation of Morton Thiokol's aerospace business in June 1989 and to other matters of $25.0 million ($0.52 per share). **u** Data for Morton Thiokol. **v** Excludes net charge for cumulative effect of change in accounting for income taxes of $14.1 million ($0.29 per share).

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
(Money figures in thousands of dollars unless otherwise indicated)														
NL Industries														
1989	$1,000,883	$170,274[a]	$1,512,315	0.9	$ 380,465	$ 83,386	$ 137,310	17.0%	124.0%	$ 2.57[a]	$0.60	2.6%	$28–18¾	9.1
1988[b]	1,007,036	134,236[c]	836,941	1.4	344,020	70,624	150,951	13.3	88.9	2.02[c]	0.20[d]	3.1	7¾–5¼[d]	—
1987[b]	859,267	87,866[e]	1,092,483	1.5	315,907	73,318	406,220	10.2	21.6	1.31[e]	0.20[d]	2.6	11–4¼[d]	—
1986	549,314	(382,197)[f,g]	1,149,950	1.1	349,854	24,499	444,901	—	—	(6.31)[f,g]	0.17	1.7	16⅛–3⅜	—
Nalco Chemical Co.														
1989	$1,070,754	$119,909	$ 892,006	2.2	$ 350,886	$ 86,435	$ 397,207	11.2%	30.2%	$ 3.01	$1.36	3.2%	$49⅞–34½	14.3
1988	994,150	105,971	794,899	2.0	311,200	61,578	433,550	10.7	24.4	2.70	1.29	3.6	39⅞–31¼	13.2
1987	841,876	80,254	696,360	1.7	304,084	57,232	396,297	9.5	20.3	2.03	1.20	3.5	45½–24	17.1
1986	736,074	63,672	536,916	1.7	280,195	63,636	358,023	8.7	17.8	1.62	1.20	4.4	31¼–23½	16.9
Olin Corp.														
1989	$2,509,000	$124,000	$1,794,000	1.3	$ 781,000	$142,000	$ 555,000	4.9%	22.3%	$ 6.02	$1.95	3.3%	$68¼–49⅜	10.2
1988	2,308,000	98,000	1,799,000	1.3	801,000	147,000	542,000	4.2	18.1	4.63	1.70	3.4	60–40	10.8
1987	1,930,000	78,000	1,583,000	1.7	727,000	115,000	598,000	4.0	13.0	3.38	1.60	3.6	56¼–32⅝	13.1
1986	1,707,261	75,226	1,464,830	1.5	719,686	127,935	574,290	4.4	13.1	3.36	1.525	3.5	53¼–34⅝	13.1
Quantum Chemical Corp.														
1989	$2,671,000	$114,100[h]	$2,910,000	1.5	$1,759,300	$583,300	$ (271,300)[i]	4.3%	—	$ 4.54[h]	$2.25[j]	3.3%	$107⅛–28½	14.9
1988	2,921,900	360,100[k]	2,881,300	0.7	1,308,600	333,500	(433,400)[i]	12.3	—	13.71[k]	2.40[l]	2.8	108¼–65½	6.3
1987	2,566,800	143,600[m]	2,519,300	1.3	1,380,200	154,200	983,500	5.6	14.6%	4.38[m]	2.20	3.4	88–42½	14.9
1986	1,729,600	55,100[n]	2,844,200	1.0	1,393,800	101,600	944,500	3.2	5.8	1.54[n]	2.20	5.7	47⅝–30	25.3
Rohm & Haas Co.														
1989	$2,661,000	$176,000[o]	$2,361,000	1.6	$1,148,000	$385,000	$1,217,000	6.6%	14.5%	$ 2.65	$1.16	3.4%	$37½–31	12.9
1988	2,535,000	230,000	2,148,000	1.7	935,000	338,000	1,113,000	9.1	20.7	3.46	1.02	3.1	37½–28	9.5
1987	2,203,000	195,000[p]	1,882,000	1.9	730,000	222,000	981,000	8.9	19.9	2.85[p]	0.86	2.2	53¼–24	13.6
1986	2,067,000	138,000[q]	1,756,000	2.0	648,000	179,000	916,000	6.7	15.1	2.01[q]	0.78	2.5	38¾–23⅞	15.6
Sigma-Aldrich Corp.														
1989	$ 441,099	$63,958	$ 472,424	2.7	$ 176,431	$ 51,703	$ 298,851	14.5%	21.4%	$ 2.59	$0.37	0.7%	$59½–43¾	19.9
1988	375,282	56,477	359,671	2.5	119,518	35,605	243,906	15.0	23.2	2.29	0.33	0.7	51¼–39¾	19.9
1987	304,858	41,889	285,343	2.9	96,975	20,616	196,012	13.7	21.4	1.70	0.29	0.7	50⅝–30¼	23.8
1986	253,097	33,958	244,875	2.5	86,111	35,461	155,689	13.4	21.8	1.38	0.25	0.7	40¼–26¾	24.3
Stepan Co.														
1989	$ 346,350	$7,840	$ 215,351	1.7	$ 122,509	$ 34,090	$ 70,741	2.3%	11.1%	$ 1.42	$0.53	2.2%	$29½–17¾	16.6
1988	333,033	13,428	185,601	1.6	104,697	20,442	66,790	4.0	20.1	2.39	0.475	2.1	25⅝–19¾	9.5
1987	288,935	10,959	172,726	1.6	98,994	25,705	59,936	3.8	18.3	1.83	0.415	2.0	26¾–14½	11.2
1986	259,787	7,513	152,794	1.5	85,607	14,322	55,029	2.9	13.6	1.265	0.37	2.6	17⅝–10⅜	11.3
Sterling Chemicals														
1989[r]	$ 580,797	$103,898	$ 329,040	1.3	$ 216,355	$ 57,592	$ 110,372	17.9%	94.1%	$ 1.77	$0.75	5.9%	$18¾–6⅞	7.2
1988[r]	698,964	213,845[s]	294,242	1.4	172,881	16,993	90,562	30.6	236.1	3.56[s]	3.17	—	17¾–14⅛	4.5
1987[r]	413,192	51,385[t]	283,375	1.2	169,119	13,174	60,184	12.4	85.4	0.86[t]	—	—	—	—
1986[u]	35,399	1,509	238,567	—	—	938	12,719	4.3	—	0.03	—	—	—	—
Union Carbide Corp.														
1989	$8,744,000	$573,000	$8,483,000	1.1	$4,584,000	$785,000	$2,320,000	6.6%	24.7%	$ 4.07	$1.00	3.6%	$33¼–22⅜	6.9
1988	8,324,000	662,000	8,389,000	1.1	4,416,000	671,000	1,784,000	8.0	37.1	4.88	1.15	5.1	28⅜–17	4.6
1987	6,914,000	232,000	7,820,000	1.3	4,344,000	502,000	1,175,000	3.4	19.7	1.76	1.50	6.2	32½–15½	13.6
1986	6,244,000	130,000[v]	7,496,000	1.2	4,379,000	524,000	930,000	2.1	14.0	1.25[v]	1.50	5.8	33⅛–18¾	20.8
Vista Chemical Corp.														
1989[r]	$ 778,902	$119,902[w]	$ 550,594	1.4	$ 341,109	$ 99,011	$ (172,619)[i]	15.4%	—	$ 8.56[w]	$1.80	3.9%	$56¾–36⅛	5.4
1988[r]	781,351	123,917[x]	500,643	1.6	275,544	48,082	119,438	15.9	103.8%	7.10[x]	0.35	0.1	61–39	7.0
1987[r]	608,887	(1,762)[f,y]	474,265	1.5	266,250	20,889	134,686	—	—	(0.13)[f,y]	0.05	0.1	55⅛–18⅝	—
1986[r]	550,097	30,212[z]	453,418	1.8	272,699	15,792	60,808	5.5	49.7	1.73[z]	0.00	0.0	18¾–17	10.3

a Excludes extraordinary net gain of $2.6 million ($0.04 per share). b Restated to reflect restructuring and spin-off of petroleum services business on Dec. 22, 1988 (except as noted). c From continuing operations; excludes net income from discontinued operations of $21.5 million ($0.32 per share). d Before restructuring. e From continuing operations; excludes net loss from discontinued operations of $107.8 million ($1.64 per share). f Net loss. g From continuing operations; excludes net income from discontinued operations of $58.0 million ($0.51 per share). h From continuing operations; excludes net income and net gain on sale of oleochemical business of $133.3 million ($5.31 per share). i Deficit. j Plus 1% stock dividend. k From continuing operations; excludes net income from discontinued oleochemical business of $22.6 million ($0.86 per share). l Excludes special dividend declared of $50 per share. m From continuing operations; excludes net income from discontinued spirits and wine operations of $108.0 million ($3.37 per share). n From continuing operations; excludes net income from discontinued spirits and wine operations of $20.5 million ($0.67 per share). o Includes net gain on sale of interest in U.K. subsidiary of $15 million ($0.23 per share) and net loss on write-off of assets of $13 million ($0.20 per share). p Includes net gain on sale of assets of $5.0 million ($0.07 per share). q Includes net loss of disposal of assets of $9.2 million ($0.13 per share). r Fiscal year ends Sept. 30. s Excludes net loss on early extinguishment of debt of $9.0 million ($0.15 per share) and net gain on cumulative effect of change in accounting for income taxes of $8.3 million ($0.14 per share). t Excludes net loss on early extinguishment of debt of $4.0 million ($0.07 per share). u For two months ended Sept. 30. v From continuing operations of $569 million ($5.49 per share) and net charges for extraordinary items of $203 million ($1.96 per share). w Includes net gain associated with change in stock option plan of $586,000. x Includes net gain associated with change in stock option plan of $1.5 million but excludes net loss on extinguishment of debt of $10.8 million ($0.62 per share). y Includes net charge associated with change in stock option plan of $55.4 million and net gain on sale of interest in Petroquimica Argentina of $5.1 million but excludes net loss on extinguishment of debt of $1.9 million ($0.12 per share). z Excludes net loss on extinguishment of debt of $1.4 million ($0.08 per share).

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
							(Money figures in thousands of dollars unless otherwise indicated)							
Witco Corp.														
1989	$1,587,788	$35,009	$1,121,358	3.4	$ 417,175	$70,387	$ 553,664	2.2%	6.3%	$1.60	$1.61	4.0%	$45⅛–34⅝	24.9
1988	1,585,856	71,621[a]	1,096,219	3.1	400,996	72,059	559,985	4.5	12.8	3.05[a]	1.39	4.0	38⅜–30⅝	11.3
1987	1,427,650	63,293	1,037,624	3.0	374,628	69,082	494,941	4.4	12.8	2.72	1.16	3.1	47⅜–26⅝	13.6
1986	1,355,018	65,215	804,086	2.4	367,789	60,102	449,783	4.8	14.5	2.93	1.05	3.2	40–26⅜	11.3
PHARMACEUTICALS														
Abbott Laboratories														
1989	$5,379,751	$859,832	$ 4,851,635	1.2	$2,090,166	$573,138	$2,726,413	16.0%	31.5%	$1.92	$0.70	2.4%	$35⅛–23⅛	15.1
1988	4,936,991	752,027	4,825,113	1.4	1,952,622	521,196	2,464,649	15.2	30.5	1.66	0.60	2.5	26⅛–21⅜	14.3
1987	4,387,876	632,559	4,385,737	1.3	1,741,557	432,736	2,093,453	14.4	30.2	1.39	0.50	1.9	33½–20	19.3
1986	3,807,634	540,460	3,865,609	1.3	1,543,267	383,389	1,778,921	14.2	30.4	1.16	0.42	1.9	27½–15¾	18.7
American Home Products Corp.														
1989	$6,747,016	$1,102,158	$ 5,114,491	3.0	$1,481,686	$250,737	$1,403,027	16.3%	78.6%	$3.53	$1.95	4.1%	$54½–40⅛	13.4
1988	5,500,533	932,184	3,967,479	2.8	1,309,314	344,464	2,332,475	16.9	40.0	3.19	1.80	4.6	42⅛–35½	12.2
1987	5,028,272	845,081	3,956,855	2.0	1,153,028	216,525	1,878,178	16.8	45.0	2.86	1.67	4.2	48⅜–31	13.9
1986	4,926,512	778,824[b]	3,819,146	2.7	929,400	204,764	2,024,869	15.8	38.5	2.59[b]	1.55	4.0	47⅜–30⅝	15.1
Bristol-Myers Squibb Co.														
1989	$9,189,000	$ 747,000[c]	$ 8,273,00	1.9	$2,350,000	$562,000	$4,860,000	8.1%	15.4%	$1.43[c]	$2.00	3.9%	$58–44	35.7
1988[d]	5,972,500	829,000	4,988,500	2.9	1,249,100	252,300	3,345,800	13.9	24.8	2.88	1.68	4.0	46½–38⅛	14.7
1987[d]	5,401,200	709,600[e]	4,549,400	2.8	1,141,900	190,000	3,046,700	13.1	23.3	2.47[e]	1.40	3.3	55¾–28¼	17.0
1986[d]	4,835,900	589,500	3,993,900	2.5	1,070,000	221,900	2,646,500	12.2	22.3	2.07	1.06	2.9	44¼–30⅛	18.0
Eli Lilly & Co.														
1989	$4,175,600	$939,500	$ 5,394,400	1.6	$2,114,600	$554,500	$3,303,500	22.5%	28.4%	$3.20	$1.35	2.4%	$68½–42⅜	17.3
1988	4,069,700	761,000	4,852,800	1.7	1,806,600	372,100	2,815,400	18.7	27.0	2.67	1.15	2.8	45¾–35½	15.3
1987	3,643,800	410,500[f]	4,859,200	1.8	1,642,500	344,100	2,646,900	11.3	15.5	1.41[f]	1.00	2.4	53⅝–28⅞	29.2
1986	3,720,400	558,200	4,117,000	1.7	1,527,600	283,000	2,260,800	15.0	24.7	2.00	0.90	2.7	41¾–25¼	16.7
Merck & Co.														
1989	$6,550,500	$1,495,400	$ 6,593,400	1.7	$2,292,500	$433,000	$3,357,300	22.8%	44.5%	$3.78	$1.64	2.4%	$80¾–56¼	
1988	5,939,500	1,206,800	5,992,100	1.7	2,070,700	372,700	2,720,400	20.3	44.4	3.05	1.28	2.4	59⅝–48	17.6
1987	5,061,300	906,400	5,533,200	1.3	1,948,000	253,700	1,969,900	17.9	46.0	2.23	0.82	1.4	74¼–40⅝	25.8
1986	4,128,900	675,700	4,967,900	1.7	1,906,200	210,600	2,431,800	16.4	27.8	1.62	0.63	1.9	43⅛–22⅜	20.3
Pfizer														
1989	$5,671,500	$681,100	$ 7,894,800	1.4	$1,784,100	$456,500	$4,105,800	12.0%	16.6%	$4.04	$2.20	3.4%	$75¾–54	16.1
1988	5,385,400	791,300	7,218,200	1.7	1,655,100	343,700	3,881,700	14.7	20.4	4.70	2.00	3.7	60¼–47⅜	11.4
1987	4,919,800	690,200	6,684,700	2.0	1,505,900	258,300	3,644,500	14.0	18.9	4.08	1.80	3.1	77–40	14.3
1986	4,476,000	660,000	4,946,700	1.9	1,351,300	196,100	3,198,200	14.7	20.6	3.90	1.64	2.8	72⅞–46¼	15.3
Schering-Plough Corp.														
1989	$3,157,900	$471,300	$ 3,440,000	1.5	$1,210,700	$186,100	$1,781,900	14.9%	26.4%	$2.09	$0.875	2.5%	$43–27⅝	16.9
1988	2,969,400	389,900	3,234,500	1.2	1,181,000	156,100	1,485,900	13.1	26.2	1.74	0.70	2.7	29⅝–22⅝	15.0
1987	2,699,300	320,700[g]	3,053,200	1.2	1,131,100	118,000	1,317,300	11.9	24.3	1.38[g]	0.51	2.4	27⅝–15⅝	15.6
1986	2,398,700	265,800	2,862,200	1.3	1,143,500	124,800	1,319,700	11.1	20.1	1.08	0.45	2.5	22–14	16.6
Upjohn Co.														
1989	$2,907,332	$310,974[h]	$ 3,246,891	1.5	$1,283,437	$242,260	$1,736,125	10.7%	17.9%	$1.67[h]	$0.94	2.7%	$42⅛–27⅝	20.9
1988	2,746,248	353,418	3,139,328	1.6	1,239,598	240,997	1,820,952	12.9	19.4	1.90	0.80	2.6	35¼–26⅞	16.3
1987	2,521,024	305,039	3,043,131	1.9	1,114,391	211,976	1,673,512	12.1	18.2	1.63	0.63	1.6	53¾–23¼	23.6
1986	2,280,325	252,646	2,664,956	1.9	981,549	201,920	1,470,216	11.1	17.2	1.35	0.51	1.8	35½–20½	20.7
Warner-Lambert Co.														
1989	$4,195,800	$412,700	$ 2,719,700	1.1	$1,132,500	$218,500	$ 989,700	9.8%	41.7%	$3.05	$1.28	2.6%	$59⅜–37¼	15.8
1988	3,908,400	340,300	2,554,100	1.1	1,053,000	189,600	849,900	8.7	40.0	2.50	1.08	3.1	39¾–30	13.9
1987	3,484,700	295,800	2,396,500	1.1	959,800	176,900	795,000	8.5	37.2	2.08	0.885	2.6	43¾–24⅛	16.4
1986	3,102,918	261,784[i]	2,479,054	1.4	819,291	137,996	870,453	8.4	30.1	1.77[i]	0.795	2.9	31½–22½	15.3

a Excludes net gain on cumulative effect of accounting change of $20.3 million ($0.81 per share). **b** Includes gain on sale of Brach confectionary business and Household Research subsidiary, before taxes, of $535 million. **c** Includes charges and expenses for integrating operations of Bristol-Myers Co. and Squibb Corp., after taxes, of $693 million ($1.32 per share). **d** For Bristol-Myers Co. **e** Includes gain on sale of orthodontic and animal health businesses, before taxes, of $80.3 million. **f** From continuing operations; includes restructuring charges, before taxes, of $271.9 million but excludes net income and net gain on sale of discontinued cosmetics business of $233.2 million ($0.79 per share). **g** Excludes nonrecurring net charge of $4.3 million ($0.02 per share). **h** From continuing operations; includes restructuring and other nonrecurring charges of $57.3 million but excludes net loss on disposal of discontinued operations of $130.0 million ($0.72 per share). **i** Excludes net nonrecurring credit from write-down and divestiture of assets and restructuring program of $47.7 million ($0.32 per share).

Chemical work force tops 1.1 million

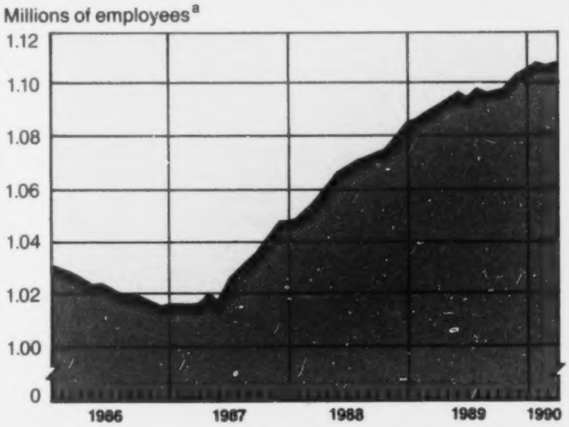
The number of people employed in the U.S. chemical industry has been rising steadily for the past three years, reaching more than 1.1 million by the end of 1989. Only once before—from 1979 to 1981—have so many people worked in the U.S. chemical industry. Production workers, too, of whom 619,000 were employed in the chemical industry at the end of 1989, are now at close to their historically high level of about 630,000 set a decade ago.

Although the past three years have seen employment grow in nearly all sectors of the chemical industry, for the decade as a whole a considerable shift has taken place in the areas where people work. When the 1980s began, two of every 10 chemical industry employees were involved in manufacturing plastics and synthetic materials, followed closely by drugs, and then by organic and inorganic chemicals. By 1989, drugs were the largest employment sector, with 22% of chemical industry employees working there. Plastics manufacture now claims 17% of the industry's work force, followed by soap and toiletries, which employs 14%.

Wages in the chemical industry rose, on average, 3% last year, keeping pace with manufacturing wages generally. The organic and inorganic chemicals sectors continue to pay the highest wages. Soap and paint makers, on average, pay the lowest, although even in these sectors, chemical workers earn about 10% more, on average, than workers in all other manufacturing jobs.

Women comprise a slightly smaller fraction of chemical workers than they do for all manufacturing—29% for the chemical industry in 1988 compared with 33% for manufacturing industries as a whole. But their numbers are increasing faster—up from 24% a decade earlier, when women held 30% of all manufacturing jobs. Some fields, particularly the drug and toiletries industries, have a significantly higher proportion of women—44% in each case—up from 40% a decade ago. No chemical field, however, employs more women than men.

Number of workers in chemical industry has grown steadily for past three years



a Seasonally adjusted employment in U.S. chemicals and allied products industry; February, March, and April 1990 figures are preliminary. **Source:** Department of Labor

INDUSTRIAL EMPLOYMENT: Plastics and drugs lead chemical industry gains in 1989

Thousands[a]	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
All manufacturing	19,612	19,403	19,024	18,965	19,260	19,378	18,434	18,781	20,170	20,285	21,040	1%	−1%
Chemicals and allied products	1,093	1,065	1,026	1,022	1,044	1,049	1,043	1,075	1,109	1,107	1,109	3	0
Industrial inorganic chemicals	135	133	130	135	142	143	151	161	162	161	162	2	−2
Plastics materials and synthetics	187	178	168	168	172	178	177	185	196	205	212	5	−1
Drugs	241	231	215	208	206	206	201	199	199	196	193	4	2
Soap, cleaners, and toilet goods	161	160	153	147	148	146	142	144	146	141	140	1	1
Paints and allied products	63	64	63	63	64	62	60	60	63	65	69	−2	−1
Industrial organic chemicals	150	147	148	154	160	162	163	171	178	174	171	2	−1
Agricultural chemicals	53	52	51	54	59	61	61	65	70	72	70	2	−3
Miscellaneous chemical products	102	101	97	94	94	92	89	91	94	93	93	1	1
Petroleum and coal products	163	162	164	169	179	189	196	201	214	198	210	1	−3
Rubber and miscellaneous plastics products	840	830	811	790	786	780	711	697	737	727	782	1	1

a Domestic employment. **Source:** Department of Labor

PRODUCTION WORKERS: Chemical employment growing faster than manufacturing as a whole

Thousands[a]	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
All manufacturing	13,375	13,254	12,970	12,877	13,092	13,285	12,530	12,742	14,020	14,214	15,068	1%	−1%
Chemicals and allied products	613	596	575	568	578	583	579	599	628	626	633	3	0
Industrial inorganic chemicals	70	67	67	69	72	73	77	86	88	87	88	4	−2
Plastics materials and synthetics	122	116	110	113	114	117	115	119	130	137	144	5	−2
Drugs	106	102	99	96	95	96	98	98	99	97	96	4	1
Soap, cleaners, and toilet goods	102	103	98	93	94	93	89	90	92	96	84	−1	2
Paints and allied products	32	31	31	30	31	30	29	29	31	33	36	3	−1
Industrial organic chemicals	88	85	83	81	82	83	84	86	90	88	89	4	0
Agricultural chemicals	33	33	32	33	37	38	37	40	44	45	45	0	−3
Miscellaneous chemical products	61	59	55	53	54	54	51	51	54	53	53	3	1
Petroleum and coal products	106	105	107	106	109	111	118	120	134	125	137	1	−3
Rubber and miscellaneous plastics products	656	646	629	615	607	608	551	534	569	559	612	2	1

a Domestic employment. **Source:** Department of Labor

EMPLOYMENT OF WOMEN: Chemical industry lags other manufacturing fields

	1988		1978	
	(thousands)	% of total	(thousands)	% of total
All manufacturing	6389.0	33%	6237.0	30%
Chemicals and allied products	310.5	29	258.2	24
Industrial inorganic chemicals	25.9	19	22.1	13
Plastics materials and synthetics	38.2	21	43.5	20
Drugs	100.7	44	74.8	40
Soap, cleaners, and toilet goods	70.1	44	54.5	40
Paints and allied products	12.6	20	12.0	17
Industrial organic chemicals	28.6	20	24.0	14
Agricultural chemicals	8.6	17	9.1	14
Miscellaneous chemical products	25.8	25	18.2	20
Petroleum and coal products	24.3	15	24.6	12
Rubber and miscellaneous plastics products	287.6	35	261.1	35

a Domestic employment. **Source:** Department of Labor

WORKWEEK: Held steady for chemical workers last year

Hours[a]	1989	1988	1987
All manufacturing	41.0	41.1	40.2
Chemicals and allied products	42.4	42.3	41.9
Industrial inorganic chemicals	42.8	43.0	42.1
Plastics materials and synthetics	43.1	43.4	42.1
Drugs	41.7	41.1	41.1
Soap, cleaners, and toilet goods	10.2	40.2	40.5
Paints and allied products	41.8	41.9	41.2
Industrial organic chemicals	44.6	44.1	43.4
Agricultural chemicals	43.4	43.3	42.9
Miscellaneous chemical products	42.4	42.1	41.5
Petroleum and coal products	44.3	44.4	43.8
Rubber and miscellaneous plastics products	41.5	41.7	40.5

a For production workers in domestic employment. **Source:** Department of Labor

EMPLOYMENT OF SCIENTISTS, ENGINEERS: Chemical industry's share is about 10% of total

Thousands[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Total, all industry	725.8	703.8	676.5	626.2	586.5	541.9	509.8	487.8	450.6	423.9	404.4
Chemicals and allied products	74.9	73.0	75.8	71.1	69.8	67.3	61.6	54.7	51.4	50.0	48.3
Industrial chemicals	23.2[b]	24.4	24.9	23.5	25.6	26.6	25.9	21.6	20.9	21.4	21.3
Drugs and medicines	31.2	29.2	31.8	30.8	30.8[b]	28.2	25.6	23.3	21.6	20.8	19.5
Other chemicals	20.5	19.4	19.1	16.7	13.4	12.1	10.1	9.8	8.9	7.8	7.5
Petroleum refining	9.5	8.6	10.4	13.5	13.3	14.7	15.6	13.0	10.8	10.1	9.9

a Full-time equivalent number of R&D scientists and engineers in industry, as of January of each year. b Partly estimated. **Source:** National Science Foundation

3 Employment in the U.S. Chemical Industry

CHEMICAL EMPLOYMENT: Slow recovery continues after sharp 1986–87 cutbacks

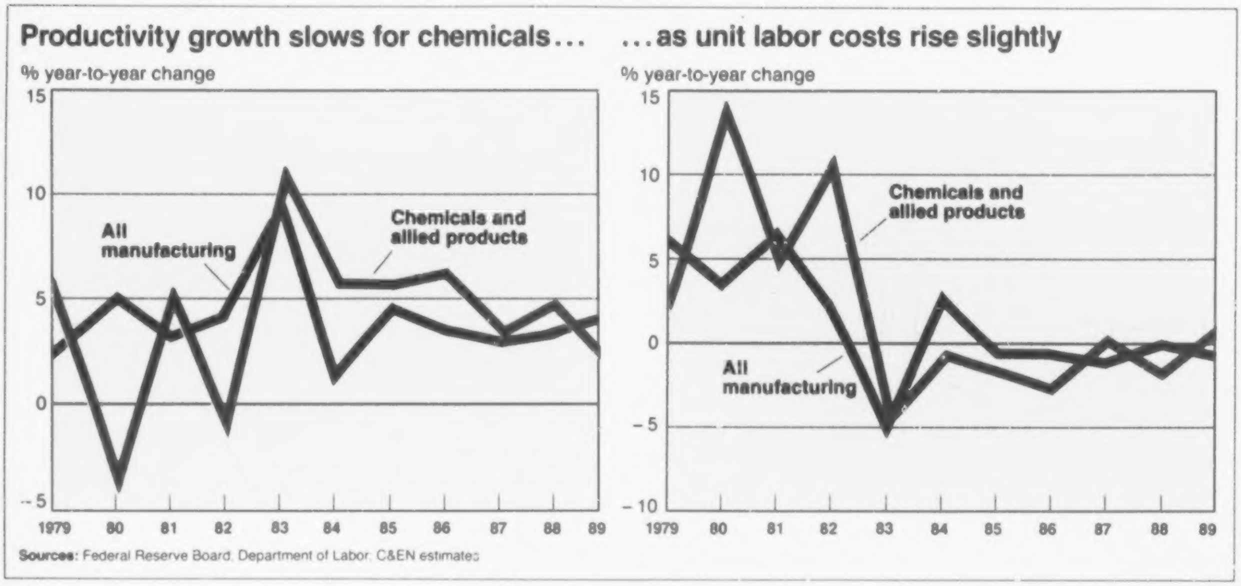
Thousands	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
Air Products	14.1	13.3	12.1	16.6	18.7	17.7	16.7	18.9	16.2	15.8	14.6
American Cyanamid	35.4	35.5	34.3	34.5	36.4	38.2	38.7	40.2	41.8	42.6	44.2
Betz Laboratories	3.4	3.1	2.0	2.6	2.5	2.5	2.3	2.2	2.2	2.1	2.0
Cabot Corp.	5.5	5.2	5.1	6.6	7.7	7.5	7.2	7.5	7.7	7.6	8.1
Chemed	5.7	5.6	4.8	4.8	4.3	4.3	4.1	3.5	3.6	3.6	3.3
Crompton & Knowles	1.7	1.6	1.3	1.3	2.3	2.3	2.4	2.3	2.5	2.8	3.0
Dow Chemical	62.1	55.5	53.1	51.3	53.2	49.8	54.5	56.6	63.8	56.8	55.9
Ethyl	5.5	10.4	10.0	10.5	10.5	11.0	13.0	14.0	14.5	15.0	16.0
H. B. Fuller	5.4	5.2	4.6	4.5	4.4	4.3	4.1	4.0	3.3	3.4	3.4
W. R. Grace	46.4	45.7	39.4	41.4	116.9	102.6	95.5	82.2	89.0	92.0	82.8
Hercules	23.3	22.7	23.2	25.1	25.4	26.3	24.2	24.5	25.9	26.1	27.4
International Flavors	4.2	4.2	4.1	3.8	3.7	3.7	3.7	3.6	3.6	3.6	3.6
International Minerals	6.9	6.9	12.9	13.9	8.7	9.0	8.4	8.4	10.6	10.6	10.3
Lubrizol	5.3	4.8	4.8	4.8	5.2	4.2	4.2	4.3	4.2	4.2	3.9
Monsanto	42.2	45.6	49.7	51.7	56.1	50.8	48.8	52.2	57.4	61.8	63.9
Nalco Chemical	5.5	5.4	5.1	4.9	5.1	4.8	4.6	4.6	4.7	4.3	4.1
Olin	15.4	16.4	14.1	13.2	14.9	17.8	18.2	17.5	20.3	21.0	21.7
PPG Industries	35.5	36.3	36.8	36.5	37.5	37.7	37.0	37.0	36.6	37.3	38.2
Rohm & Haas	13.0	12.4	12.0	12.1	11.8	11.9	11.4	11.5	13.5	13.2	13.3
Stepan	1.2	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.9
Union Carbide	46.0	44.0	43.1	50.3	91.5	98.4	99.5	103.2	110.3	116.1	115.8
TOTAL EMPLOYEES	**383.7**	**380.8**	**373.6**	**391.3**	**517.7**	**505.7**	**499.3**	**499.1**	**532.6**	**540.6**	**536.4**
ANNUAL CHANGE	**0.8%**	**1.9%**	**–4.5%**	**–24.4%**	**2.4%**	**1.3%**	**0.1%**	**–6.3%**	**–1.5%**	**0.8%**	**4.1%**
SALES PER EMPLOYEE ($ thousands, current)	**$189.5**	**$179.3**	**$160.7**	**$135.8**	**$114.6**	**$115.8**	**$110.4**	**$107.9**	**$109.6**	**$102.0**	**$ 92.9**
SALES PER EMPLOYEE ($ thousands, constant 1982[a])	**$153.9**	**$154.0**	**$151.0**	**$132.5**	**$110.5**	**$112.6**	**$110.1**	**$107.9**	**$111.4**	**$114.5**	**$122.0**

Note: Data are not restated for acquisitions, divestitures, or similar developments. a Based on producer price index for chemicals and allied products. **Source:** Company data

WAGES: Chemical industry hourly earnings edge above $13 per hour in 1989

	Hourly earnings[a]				Weekly earnings[a]			
	1989	1988	1987	1979	1989	1988	1987	1979
All manufacturing	$10.47	$10.18	$ 9.91	$6.40	$429.27	$417.99	$406.31	$269.34
Chemicals and allied products	13.06	$12.67	12.37	7.60	533.74	535.94	523.25	318.44
Industrial inorganic chemicals	14.21	13.87	13.56	8.26	608.19	596.41	574.94	347.75
Plastics materials and synthetics	13.39	13.04	12.60	7.48	577.11	565.94	543.06	314.91
Drugs	12.51	12.07	11.62	6.93	521.67	496.08	483.39	284.82
Soap, cleaners, and toilet goods	11.28	11.05	10.90	7.18	453.46	444.21	447.99	290.79
Paints and allied products	11.65	11.24	10.84	6.80	486.97	470.96	452.03	280.16
Industrial organic chemicals	15.58	15.05	14.89	9.02	694.87	663.71	656.65	391.47
Agricultural chemicals	12.74	12.34	11.92	7.26	552.92	534.32	510.18	311.45
Miscellaneous chemical products	11.92	11.54	11.36	7.06	505.41	485.83	471.44	292.99
Petroleum and coal products	15.44	14.98	14.58	9.36	683.99	665.11	641.52	409.97
Rubber and miscellaneous plastics products	9.42	9.14	8.92	5.97	390.93	381.14	371.07	241.79

a For production workers in domestic employment. **Source:** Department of Labor



Productivity growth slows for chemicals... ...as unit labor costs rise slightly

Sources: Federal Reserve Board, Department of Labor, C&EN estimates

Productivity of workers in the U.S. chemical industry improved slightly last year. But companies had to pay their production employees more, as well, causing unit labor costs also to rise.

As a result, changes for both productivity and labor costs were less favorable for the chemical industry than for all manufacturing, the first time this has happened since 1983.

Using data from the Federal Reserve Board and the Department of Labor, C&EN calculates that productivity in the chemical industry increased 2.3% in 1989, a considerable slowing from the 4.4% increase that occurred in 1988. In fact, not since 1982, when productivity in the industry actually fell slightly, has the showing been so poor. And the increase for chemicals also was less than that in all manufacturing.

Production of chemicals and allied products increased 6% in 1989, while the Labor Department's index of aggregate weekly hours worked by production employees rose just 3%. By contrast, production in all manufacturing was up almost 4%, while workhours were flat. The result was a 3.8% increase in productivity for manufacturing industries as a whole.

However, while chemical productivity was rising, hourly wages in the industry were increasing a bit faster, so that unit labor costs were higher, as well. According to government figures, hourly production wages rose 3.1% in 1989 from the year before. This resulted in an 0.8% increase in the industry's unit labor costs; in contrast, unit labor costs for chemicals and allied products fell 1.9% in 1988. Last year's increase was only the second in the past eight years, other than a very slight rise that took place in 1987.

For all manufacturing, unit labor costs delcined last year, after having been flat in 1988. C&EN's calculations show these costs dropping 0.9% in 1989 from 1988 levels as the 2.9% rise in hourly production wages was outstripped by a 3.8% increase in output per workhour.

PRODUCTIVITY: Modest growth in chemical industry keeps labor costs relatively low

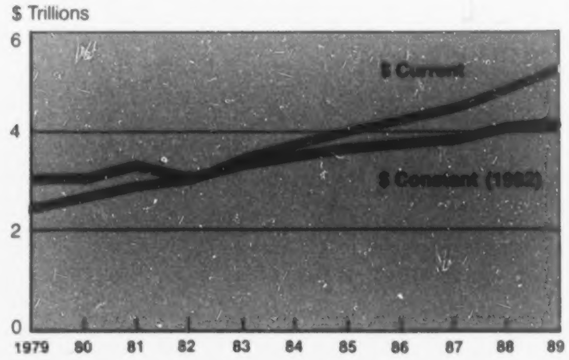
Indexes, 1977 = 100	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
CHEMICALS AND ALLIED PRODUCTS											
Production	160.1	151.2	140.2	133.0	127.1	121.6	113.9	103.8	112.6	106.4	113.3
Workhours	101.3	98.3	94.7	92.6	94.1	95.0	93.9	95.2	101.7	101.0	103.1
Productivity[a]	158.0	154.5	148.0	143.6	135.1	128.0	121.3	109.0	110.7	105.3	109.9
Hourly production wages	203.1	197.0	192.4	186.1	180.1	172.7	164.8	155.0	141.8	129.2	118.2
Unit labor costs[b]	128.5	127.5	130.0	129.6	133.3	134.9	135.9	142.2	128.1	122.6	107.6
ALL MANUFACTURING											
Production	148.2	142.7	134.7	129.2	126.4	123.4	113.9	102.2	110.5	108.2	110.7
Workhours	96.1	96.1	93.4	92.0	93.1	94.8	88.2	87.0	97.9	98.9	106.4
Productivity[a]	154.2	148.5	144.2	140.4	135.8	130.2	129.1	117.5	112.9	109.4	104.0
Hourly production wages	184.3	179.1	174.0	171.1	166.9	161.5	155.4	149.6	140.7	128.1	118.0
Unit labor costs[b]	119.5	120.6	120.7	121.8	122.9	124.1	120.3	127.4	124.7	117.1	113.4

[a] Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. [b] Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. **Sources:** Federal Reserve Board, Department of Labor, C&EN estimates

4 Markets for the U.S. Chemical Industry

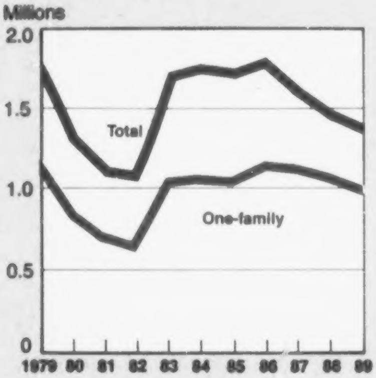
Any question why last year, although a strong one by most past standards for chemical producers, was not quite the banner year that 1988 had been can be settled by a glance at the data graphed on these two pages. The U.S. economy generally continued to be healthy; the nation's total output of goods and services and spending on the part of its consumers both increased nearly 3%, after adjustment for inflation. That's not quite so good a performance as earlier in the current economic upswing, but still good enough to keep industry robust and demand for chemicals high.

Even so, for some of the key markets of the chemical industry, 1989 was a downbeat year. For one of the biggest outlets for plastics, synthetic fibers, and coatings, new housing activity slackened for the third year in a row, with the number of housing starts declining 7% to the lowest level since the recession year of 1982. This year, moreover, home building still is in the doldrums.



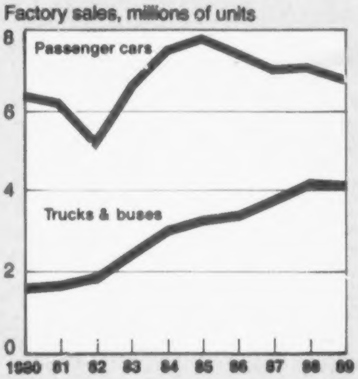
Gross national product

Source: Department of Commerce



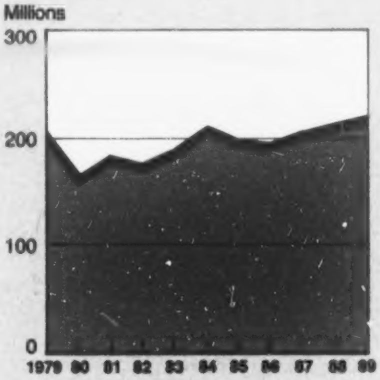
Housing starts

Source: Bureau of the Census



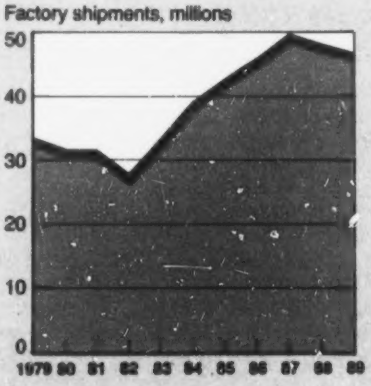
Motor vehicles

Source: Motor Vehicle Manufacturers Association



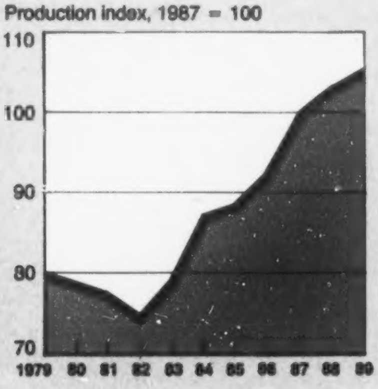
Tires and tubes

Source: Rubber Manufacturers Association



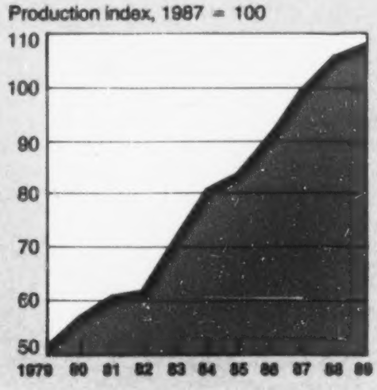
Major home electrical appliances

Source: Association for Home Appliance Manufacturers



Furniture and fixtures

Source: Federal Reserve Board



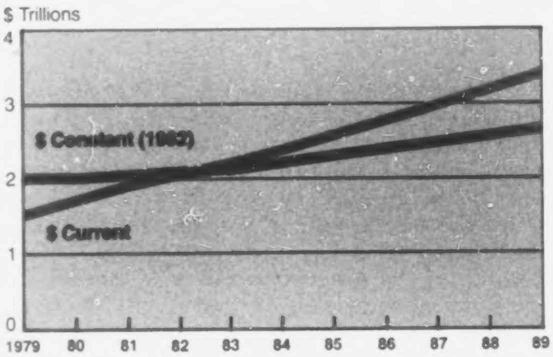
Miscellaneous plastics products

Source: Federal Reserve Board

U.S. assembly lines also turned out fewer motor vehicles last year. Production of passenger cars fell 4% to the fewest since 1983, while the decade-old advance in truck assemblies came to a halt. This year, with sales trailing last year's volume, auto production through the first five months has been cut by more than 20% from a year ago. Last year cutbacks showed up, as well, for major home appliances such as refrigerators, ranges, and dishwashers. Even the recent boom in demand for microwaves ground to a halt.

Not all the industries that consume chemical products were hurting, to be sure. Buoyed by consumer spending, apparel makers hiked production 2%, for instance. And output also edged higher for furniture and floor coverings. This year, moreover, with consumers likely to again be spending more than ever and the pace of the economy expected to pick up, demand for chemicals is not likely to deteriorate further.

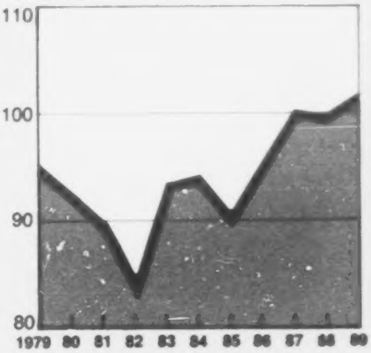
Personal consumption expenditures



Source: Department of Commerce

Textile mill products

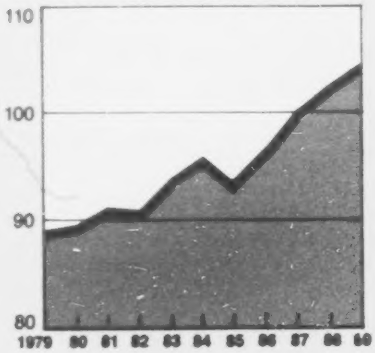
Production index, 1987 = 100



Source: Federal Reserve Board

Apparel

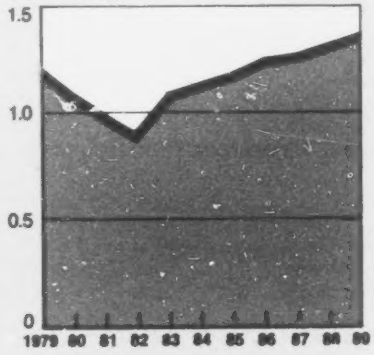
Production index, 1987 = 100



Source: Federal Reserve Board

Floor coverings

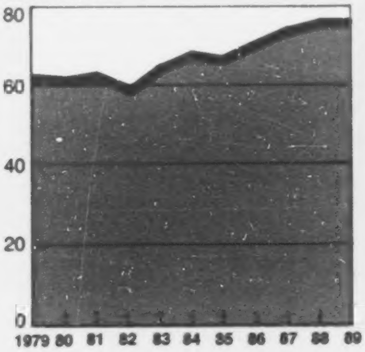
Billions of sq yd



Source: Bureau of the Census

Paper and paperboard

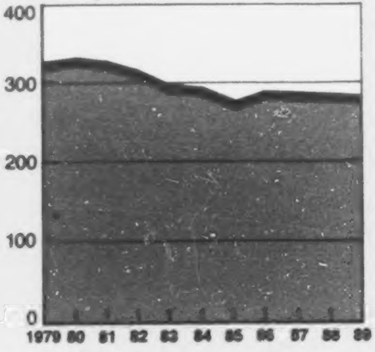
Millions of tons



Source: American Paper Institute

Glass containers

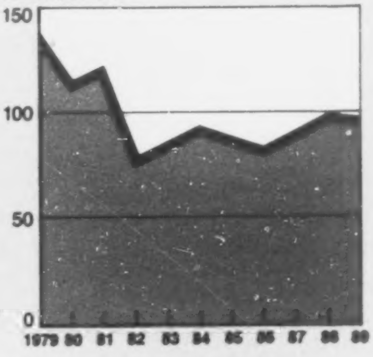
Millions of gross



Source: Bureau of the Census

Steel

Millions of tons



Source: American Iron & Steel Institute

Gains continue for U.S. trade in chemicals

Last year was another good one for U.S. foreign trade. The troublesome trade deficit, which has persisted throughout most of the 1970s and all of the 1980s, dropped sharply in 1989 for the second year in a row. And the surplus in U.S. chemical trade, one of the few consistently bright spots in the overall U.S. trade picture, continued to grow, as it has since 1985.

Total U.S. exports hit $364 billion last year, up 13% from 1988. That's only half the increase recorded in 1988, but coupled with an increase of only 7% in imports, to $473 billion, it still was enough to shave almost $10 billion off the overall deficit. At the end of last year, the deficit stood at nearly $109 billion, still uncomfortably high, to be sure, but not nearly so bad as the $153 billion deficit that existed as recently as 1987.

Meanwhile, U.S. trade in chemicals continues to show its characteristic strength. Exports increased 13% last year to a record $36.5 billion. Only West Germany, which exported $44 billion worth of chemicals, surpassed the U.S. in its foreign sales of chemicals. Growth in imports of chemicals into the U.S., on the other hand, was much lower. Imports topped the $20 billion mark for the first time, but increased only 4% for the year. As a result, the U.S. trade surplus in chemicals rose from $12.4 billion in 1988 to a heady $15.7 billion.

U.S. chemical producers chalked up their impressive performance in sales abroad despite appreciation of the U.S. dollar against most foreign currencies. A stronger dollar, of course, makes U.S. exports more costly overseas and hence less competitive in international markets. Nevertheless, the U.S. upped its share of world chemical exports from 1988's 13.5% to 14.6% last year.

U.S. TOTAL TRADE BALANCE:
Rising exports shrink deficit

$ Billions	1989	1988	1987	1979
Total exports	$ 364.3	$ 322.4	$ 252.9	$181.6
Total imports	472.9	440.9	405.9	206.3
Trade balance	-108.6	-118.5	-153.0	-24.7

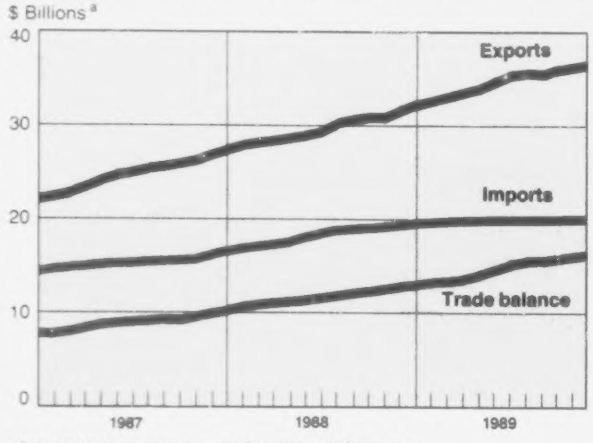
Source: Department of Commerce

U.S. CHEMICAL TRADE BALANCE:
Surplus expands as exports strengthen

$ Millions	1989	1988	1987	1979
Chemical exports	$36,485	$32,300	$26,381	$17,306
Chemical imports	20,752	19,876	16,213	7,485
Chemical trade balance	15,733	12,424	10,168	9,821

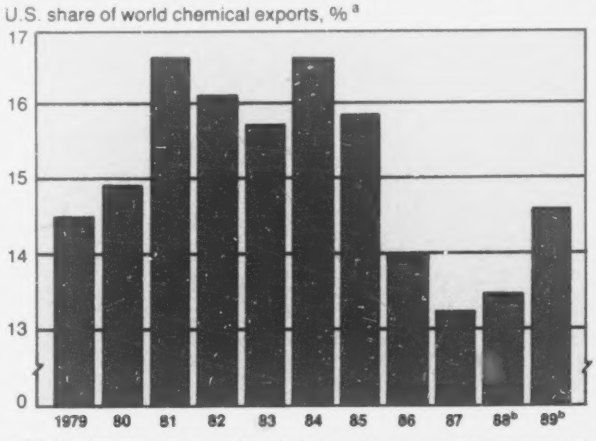
Source: Department of Commerce

U.S. chemical trade surplus widens more...



[a] Running 12-month totals. **Source:** Departmen t of Commerce

...as U.S. exports win bigger market share



[a] U.S. chemical exports as a percentage of total world chemical exports less U.S. chemical imports. [b] C&EN estimates.

U.S. TRADE: **Most markets show gains**

$ Millions	1989	1988	1987	1979
U.S. CHEMICAL EXPORTS				
Canada	$ 4,210	$ 3,800	$ 3,277	$ 1,994
Latin America	5,419	5,145	4,407	3,814
Western Europe	10,891	9,276	7,987	5,585
Eastern Europe	409	341	344	200
Communist Asia	1,137	1,388	808	125
Japan	4,664	4,002	3,422	1,652
Middle East	542	549	423	387
Rest of Asia	6,624	5,782	4,121	2,204
Australia	1,364	1,080	834	608
Africa	702	600	500	465
Other	522	337	258	272
TOTAL	**$36,485**	**$32,300**	**$26,381**	**$17,306**
U.S. CHEMICAL IMPORTS				
Canada	$ 3,938	$ 3,782	$ 3,052	$ 2,362
Latin America	1,200	1,324	942	405
Western Europe	10,582	10,212	8,220	3,449
Eastern Europe	208	219	165	107
Communist Asia	273	234	200	60
Japan	2,373	2,187	2,150	616
Middle East	371	298	238	48
Rest of Asia	985	824	698	148
Australia	291	322	235	158
Africa	61	103	74	49
Other	474	371	239	83
TOTAL	**$20,752**	**$19,876**	**$16,213**	**$ 7,485**

Source: Department of Commerce

WORLD TRADE: **U.S. leads in export growth**

$ Millions	1989	1988	1987	1979
CHEMICAL EXPORTS				
World	$270,480[a]	$259,400[a]	$214,824	$126,530
U.S.	36,485	32,300	26,381	17,306
Canada	6,184	6,387	4,736	2,897
EC, 12 countries	147,406	144,275	119,918	70,889
Belgium-Luxembourg	14,010	13,043	10,444	6,644
France	23,980	23,634	20,439	11,646
Italy	10,782	10,528	8,745	5,810
Netherlands	19,321	18,839	16,740	10,325
U.K.	20,038	20,215	17,285	10,451
West Germany	44,184	43,848	38,401	22,415
Switzerland	10,890	11,137	10,002	5,354
Japan	14,776	13,964	11,662	6,100
CHEMICAL IMPORTS				
U.S.	$ 20,752	$ 19,876	$ 16,213	$ 7,485
Canada	7,791	6,976	5,333	3,076
EC, 12 countries	120,108	113,335	96,683	54,450
Belgium-Luxembourg	11,648	10,672	8,698	5,376
France	20,637	19,619	16,892	9,890
Italy	17,220	16,084	13,689	6,992
Netherlands	11,577	10,840	9,653	5,760
U.K.	17,431	16,793	13,680	7,232
West Germany	23,361	24,274	21,503	12,399
Switzerland	6,552	6,731	5,376	3,156
Japan	15,948	14,830	11,845	5,178

[a] C&EN estimates. **Sources:** United Nations, Organization for Economic Cooperation & Development, European Community, individual government agencies

U.S. TRADE, BY PRODUCTS: **Export surge led by organic chemicals and plastics**

	Chemical exports				Chemical imports			
$ Millions	1989	1988	1987	1979	1989	1988	1987	1979
Organic chemicals	$10,609	$ 9,381	$ 7,550	$ 5,055	$ 7,042	$ 6,953	$ 5,408	$2159
Plastics and resins	7,928	7,277	5,492	3,241	3,316	2,433	1,987	626
Medicinals and pharmaceuticals	3,660	3,941	3,182	1,591	2,086	1,859	1,456	441
Inorganic chemicals	2,986	2,702	2,112	2,712	2,239	2,498	2,030	1106
Fertilizers, manufactured	2,821	2,498	2,259	1,404	999	1,021	795	976
Pesticides and disinfectants[a]	32	910	732	516	28	577	398	190
Radioactive materials	1,333	868	1,017	937	992	1,098	1,012	953
Flavors, perfumes, cosmetics, and toiletries	1,053	709	579	399	968	932	796	263
Pigments, paints, and varnishes	772	449	411	273	515	395	427	76
Cleaning and polishing materials	416	395	357	290	197	260	205	73
Dyeing, tanning, and coloring materials	325	258	217	177	618	610	621	185
Explosives and pyrotechnics	123	91	91	62	131	118	110	58
Miscellaneous	4,427	2,821	2,382	1,649	1,621	1,122	968	379
TOTAL	**$36,485**	**$32,300**	**$26,381**	**$17,306**	**$20,752**	**$19,876**	**$16,213**	**$7485**

[a] Revised classification results in 1989 data being not comparable with previous years. **Source:** Department of Commerce

6 Foreign Chemical Industries—**Western Europe**

Profitability remains relatively strong

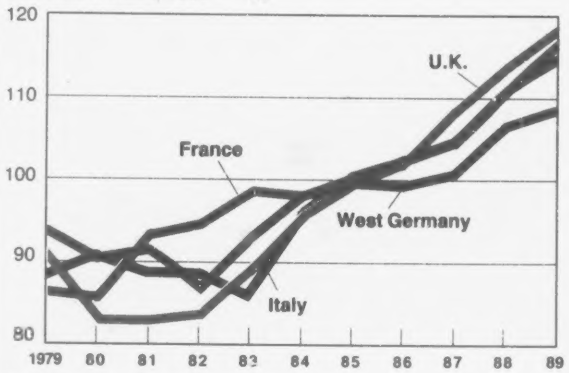
Mergers and divestitures led to several shifts among the lineup of top Western European chemical companies last year, with one completely new key player, Italy's Enimont, appearing for the first time. However, as in previous years, the big three West German chemical firms BASF, Hoechst, and Bayer were the sales leaders, with the U.K.'s ICI following them closely.

Throughout Western Europe, 1989 was a solidly profitable year, one of the best on that score, in fact, in the industry's history. In past years, when business was generally good, chemical companies tended to produce as much as their plants could turn out, chasing volume rather than profits. Last year, however, they showed a marked restraint, so that production of many major chemicals declined.

Despite the cutbacks in output, though, the industry continued to contribute favorably to the balance of trade for nearly all countries in the region.

Chemical growth strongest in France, U.K.

Production index, 1985 = 100



Source: European Chemical Industry Federation (CEFIC)

CHEMICAL INDUSTRY TRENDS: **Sales and output growth slowed in 1989 but prices rose**

$ Billions (U.S.)	1989	1988	1987	1986	1985
WEST GERMANY					
Sales	$ 85.0	$ 85.7	$ 78.0	$ 64.5	$ 50.5
Exports	45.7	45.5	40.2	33.2	26.1
Imports	27.3	25.6	22.6	18.8	15.0
Capital spending	6.1	6.0	5.3	3.5	2.4
Production index[a]	107.8	106.5	101.1	99.1	100.0
Price index[a]	95.2	92.4	91.1	94.2	100.0
Employees (thousands)	581	575	572	567	557
FRANCE[b]					
Sales	$ 54.6	$ 53.5	$ 47.4	$ 40.7	$ 31.8
Exports	21.1	21.9	19.0	15.7	12.8
Imports	19.6	18.2	15.4	12.5	10.0
Capital spending	3.2	2.9	2.5	1.9	1.3
Production index[a]	117.0	111.4	104.1	101.0	100.0
Price index[a]	103.6	98.8	96.3	97.5	100.0
Employees (thousands)	268	257	268	268	272
U.K.[b]					
Sales	$ 44.2	$ 44.0	$ 36.9	$ 30.6	$ 26.3
Exports	20.2	20.2	17.3	14.3	12.1
Imports	17.1	16.6	13.7	11.0	9.0
Capital spending	3.4	3.1	2.3	1.9	1.6
Production index[a]	118.7	113.9	109.0	101.1	100.0
Price index[a]	116.4	111.5	105.8	101.4	100.0
Employees (thousands)	320	320	336	336	336

$ Billions (U.S.)	1989	1988	1987	1986	1985
ITALY					
Sales	$ 44.2	$ 43.8	$ 37.5	$ 30.7	$ 24.5
Exports	11.5	10.9	9.3	7.8	6.6
Imports	18.4	17.1	14.7	12.0	9.3
Capital spending	2.3	2.1	1.8	1.3	0.9
Production index[a]	114.6	112.5	103.6	101.4	100.0
Price index[a]	110.2	107.5	100.4	97.3	100.0
Employees (thousands)	220	223	225	230	233
SPAIN[c]					
Sales	$ 32.5	$ 30.4	$ 25.8	$ 20.7	$ 16.1
Exports	5.1	4.9	4.2	3.1	2.9
Imports	8.9	7.6	6.3	4.7	3.1
Capital spending	0.8	0.7	0.5	0.4	0.3
Production index[a]	128.6	122.5	112.4	105.0	100.0
Price index[a]	108.3	104.6	102.5	101.0	100.0
Employees (thousands)	240	239	239	239	240
BELGIUM[b,c,d]					
Sales	$ 23.5	$ 22.7	$ 19.8	$ 17.2	$ 14.1
Exports	17.6	16.4	14.7	12.2	9.6
Imports	14.5	13.5	10.7	8.6	6.9
Capital spending	1.8	1.6	1.0	0.7	0.4
Production index[a]	125.4	120.2	110.6	102.6	100.0
Price index[a]	102.0	96.5	94.0	97.7	100.0
Employees (thousands)	95	92	91	91	90

$ Billions (U.S.)	**1989**	**1988**	**1987**	**1986**	**1985**
NETHERLANDS					
Sales	$ 22.4	$ 22.4	$ 19.5	$ 16.0	$ 13.9
Exports	22.1	21.8	19.0	15.7	12.9
Imports	13.6	12.6	11.5	9.5	8.0
Capital spending	2.0	1.5	1.5	1.2	0.8
Production index[a]	117.0	112.0	104.0	100.0	100.0
Price index[a]	92.0	88.0	87.0	85.4	100.0
Employees (thousands)	93	92	91	91	89
SWITZERLAND[b]					
Sales	$ 12.6	$ 12.7	$ 11.5	$ 9.3	$ 6.7
Exports	10.9	10.8	9.8	7.9	5.7
Imports	6.6	6.4	5.6	4.7	3.6
Production index[a]	119.0	109.4	105.3	102.1	100.0
Price index[a]	93.0	91.9	90.8	97.3	100.0
Employees (thousands)	72	70	69	68	66
SWEDEN					
Sales	$ 7.4	$ 7.5	$ 6.3	$ 5.0	$ 4.1
Exports	3.7	3.6	3.0	2.5	1.9
Imports	4.7	4.6	3.9	3.2	2.7
Capital spending	0.6	0.5	0.5	0.4	0.3
Production index[a]	118.4	119.6	106.3	99.3	100.0
Price index[a]	116.0	110.5	103.2	101.6	100.0
Employees (thousands)	42	43	45	42	43
AUSTRIA[c]					
Sales	$ 6.9	$ 7.0	$ 6.1	$ 3.5	$ 2.9
Exports	3.0	3.0	2.4	1.9	1.6
Imports	4.0	3.8	3.4	2.7	2.1
Capital spending	0.7	0.6	0.5	0.5	0.3
Production index[a]	104.1	100.0	87.3	100.8	100.0
Employees (thousands)	57	56	55	35	36
PORTUGAL					
Sales	na	$ 4.8	$ 1.7	$ 1.5	$ 1.1
Exports	$ 0.8	0.8	0.6	0.5	0.4
Imports	2.1	1.9	1.8	0.9	0.6
Production index[a]	170.8	163.2	151.9	112.0	100.0
Employees (thousands)	na	51	51	51	51

$ Billions (U.S.)	**1989**	**1988**	**1987**	**1986**	**1985**
IRELAND[b]					
Sales	$ 3.7	$ 3.1	$ 2.5	$ 2.2	$ 1.8
Exports	3.3	2.5	1.9	1.7	1.5
Imports	2.2	2.0	1.7	1.4	1.2
Production index[a]	150.5	124.1	108.1	99.2	100.0
Price index[a]	96.8	93.4	91.7	96.8	100.0
Employees (thousands)	13	12	12	12	12
DENMARK					
Sales	$ 3.6	$ 3.6	$ 3.7	$ 2.8	$ 2.1
Exports	2.8	2.7	2.4	1.9	1.5
Imports	3.1	3.1	2.8	2.4	1.9
Capital spending	0.3	0.3	0.3	0.2	0.1
Production index[a]	109.0	107.0	105.4	108.0	100.0
Price index	109.0	104.0	99.0	97.4	100.0
Employees (thousands)	26	26	26	26	25
FINLAND					
Sales	na	$ 3.5	$ 3.6	$ 3.1	$ 2.4
Exports	$ 0.8	0.6	0.6	1.2	1.0
Imports	1.3	1.0	1.1	2.1	1.6
Capital spending	na	0.4	0.5	0.4	0.3
Production index[a]	116.7	113.4	92.1	102.1	100.0
Price index[a]	na	102.4	95.0	95.5	100.0
Employees (thousands)	na	20	24	24	25
NORWAY					
Sales	$ 3.3	$ 3.1	$ 2.9	$ 2.3	$ 2.0
Exports	1.9	1.9	1.6	1.3	1.2
Imports	1.9	1.9	1.6	1.4	1.1
Capital spending	na	0.2	0.2	0.2	0.1
Production index[a]	109.0	103.0	103.0	100.0	100.0
Price index[a]	122.0	114.0	106.0	101.5	100.0
Employees (thousands)	14	14	15	15	15

a 1985 = 100. **b** Excludes fibers. **c** Includes rubber and plastics processing. **d** Includes Luxembourg for exports and imports. **na** = not available. **Sources:** National agencies and European Chemical Industry Federation (CEFIC)

NOTE ON CURRENCY CONVERSION

For monetary statistics in this section, European currencies were converted to U.S. dollars by the following conversion rates:

	$1.00 (U.S.) is equivalent to:				
	1989	**1988**	**1987**	**1986**	**1985**
Austria (schillings)	13.23	12.35	12.65	15.27	20.69
Belgium (francs)	39.40	36.77	37.33	44.67	59.38
Denmark (crowns)	7.31	6.73	6.84	8.09	10.60
Finland (marks)	4.29	4.18	4.40	5.07	6.20
France (francs)	6.38	5.96	6.01	6.93	8.99
Ireland (pounds)	0.705	0.654	0.672	0.745	0.935
Italy (lire)	1372	1302	1297	1491	1909
Netherlands (guilders)	2.12	1.98	2.03	2.45	3.32
Norway (crowns)	6.90	6.52	6.74	7.39	8.60
Portugal (escudos)	157.5	144.0	141.0	150.0	170.0
Spain (pesetas)	118.38	116.49	123.48	140.05	170.04
Sweden (crowns)	6.45	6.13	6.34	7.14	8.60
Switzerland (francs)	1.64	1.46	1.49	1.80	2.46
U.K. (pounds)	0.610	0.562	0.610	0.682	0.772
West Germany (marks)	1.88	1.76	1.80	2.17	2.94

Source: International Monetary Fund

MAN-MADE FIBERS: **Production expands only moderately overall**

Millions of lb	1989		1988		1987		1986		1985		Change, 1988–89	
	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics
West Germany	1841	394	1817	376	1806	356	1738	354	1764	372	1%	5%
Italy	1412	77	1452	70	1441	64	1430	66	1409	67	−3	10
Turkey	645	20	592	20	572	18	504	18	409	18	9	0
Spain	592	88	590	81	591	78	601	80	633	80	0	9
U.K.	493[a]	255[b]	515[a]	238[b]	513[a]	208[b]	524[a]	207[b]	557[a]	247[b]	−4	7
Benelux countries	521	119	385	119	399	109	379	108	365	95	35	0
France	392	4	392	33	382	50	392	45	427	44	0	−88
Switzerland	264	0	255	0	227	0	216	0	226	0	4	—
Ireland	207	0	176	0	172	0	162	0	140	0	18	—
Portugal	141	2	128	2	139	2	136	2	134	1	10	0
Austria	77	301	70	290	68	264	61	271	63	265	10	4
Finland	7	143	7	132	4	118	3	121	3	134	0	8

a Includes cellulose acetate filament. b Excludes cellulose acetate filament. **Source:** Comité International de la Rayonne et des Fibres Synthétiques

PRODUCTION: **Declines far outnumber increases among major chemicals in 1989**

Millions of lb	1989	1988	1987	1986	Change 1988–89
FRANCE					
Sulfuric acid	9141	8846	8618	8826	3%
Hydrochloric acid	1525	1507	1427	1381	1
Chlorine	3185	3121	2971	3151	2
Sodium hydroxide	3370	3258	3123	3304	3
Ammonia	3249	4031	4466	4455	−19
Benzene	1474	1544	1439	1332	−5
Toluene	74	104	72	83	−29
Xylenes	372	493	284	250	−25
Ethylene	5562	5361	5319	4980	4
Propylene	3480	3298	3073	2283	6
Butadiene	724	737	677	641	−2
Formaldehyde	221	193	180	176	14
Polyethylene	2549	2620	2523	2471	−3
Polypropylene	1544	1278	1159	1034	21
Polystyrene	1192	1177	1166	1089	1
Polyvinyl chloride	2350	2237	2039	1960	5
Synthetic rubber	1300	1251	1184	1193	4
Phosphate fertilizers[a]	594	700	1209	1267	−15
ITALY					
Sulfuric acid	7747[b]	9478	9590	9170	−18
Nitric acid	2436[b]	2625	2629	2402	−7
Hydrochloric acid	1390[b]	2218	1496	na	−37
Phosphoric acid	610[b]	785	843	829	−22
Chlorine	2632[b]	2385	2294	2106	−1
Sodium hydroxide	2602[b]	2618	2676	2294	−1
Sodium perborate	271[b]	242	245	212	12
Ammonia	3849[b]	3846	3839	4155	0
Benzene	1433[b]	1368	1311	1107	5
Toluene	326[b]	480	402	512	−32
Xylenes	1025[b]	986	1067	893	4
Formaldehyde	257[b]	277	297	297	−7
Acetic acid	106[b]	145	140	116	−27
Carbon black	442[b]	442	420	418	0
Polyethylene	1927[b]	1822	1691	1504	−6
Polystyrene	619[b]	627	664	785	−1
Polyvinyl chloride	1819[b]	1740	1380	1408	−5
Nitrogen fertilizers[c]	6114[b]	7176	6999	6948	−15
U.K.					
Sulfuric acid	4744	4967	4797	5125	−4
Hydrochloric acid[d]	366	368	384	346	−6
Chlorine	na	na	2256	2143	—
Benzene	2292	2072	2005	1876	11
Ethylene	4346	4464	3955	3828	−3
Propylene	1753	2985	1929	1901	−41%
Butadiene	497	527	509	424	−6
Titanium dioxide[d]	593	586	562	506	1
Acetone	287	280	259	271	2
Formaldehyde	189	246	250	227	−23
Polyethylene	989[b]	1015	876	940	−3
Polypropylene	657[b]	692	611	652	−5
Polyvinyl chloride	383[b]	353	390	400	8
Synthetic rubber	685	688	565	636	0
WEST GERMANY					
Sulfuric acid	7165	7186	7260	7344	0
Hydrochloric acid	2107	2160	2179	2048	−2
Nitric acid	4807	5098	5818	6210	−6
Chlorine	7574	7701	7595	7538	−2
Sodium hydroxide	7370	7602	7523	7485	−3
Sodium carbonate	3175	3089	3195	3173	3
Sodium sulfate	379	385	361	359	−2
Carbon black	884	836	796	844	6
Ammonia	4573	4816	5098	4146	−5
Benzene	3443	3536	3316	3373	−3
Toluene	919	1013	884	1052	−9
Xylenes	1345	1296	1102	1190	4
Aniline	376	386	309	408	−3
Ethylene	6588	6889	6118	5868	−4
Propylene	3819	3396	3467	3093	12
Butadiene	1579	1677	1543	1505	−6
Ethylene oxide	1482	1381	1223	1098	7
Ethylene glycol	543	521	536	500	4
Propylene oxide	1299	1209	1181	1174	7
Propylene glycol	399	427	379	395	−7
***n*-Butanol**	741	685	689	689	8
Acetaldehyde	709	789	727	686	−10
Acetic acid	701	754	704	653	−7
Ethanol	224	228	240	217	−2
Methanol	1535	na	na	1016	—
Formaldehyde	1534	1505	1341	1265	2
Phthalic anhydride	506	612	522	433	−17
Polyethylene	3064	3235	2980	2785	−5
Polyvinyl chloride	2948	3105	2904	2732	−5
Synthetic rubber	1119	1101	1035	1026	2
Nitrogen fertilizers[c]	1500[e]	na	1674[f]	1684[f]	—
Phosphate fertilizers[a]	197	na	na	311	—

a As P_2O_5. b C&EN estimates. c As N. d Manufacturers' sales. e Includes calcium cyanide fertilizers. f Excludes calcium cyanamid fertilizers. na = not available. **Sources:** Government agencies for each country

COMPANY RESULTS: Profitability remains strong and capital and R&D spending edge higher

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
BASF (West Germany)						
1989	$25,328.2	$1071.9	4.2	$2104.3	$1039.4	137.0
1988	24,925.0	813.8	3.3	1985.8	1016.5	134.8
1987	22,354.4	586.1	2.6	1532.2	896.1	133.8
1986	18,650.2	419.4	2.2	1224.4	676.5	131.5
Hoechst (West Germany)						
1989	$24,413.8	$1133.0	4.6%	$1700.5	$1394.1	169.3
1988	23,275.0	1144.9	4.9	1579.5	1372.7	164.5
1987	20,531.1	848.9	4.1	1330.0	1231.7	167.8
1986	17,518.0	644.7	3.7	1234.6	985.3	181.2
Bayer (West Germany)						
1989	$23,031.4	$1125.5	4.9%	$1833.5	$1433.5	170.2
1988	22,993.2	1090.3	4.7	1786.9	1397.7	165.7
1987	20,635.0	857.8	4.2	1425.0	1301.7	164.4
1986	18,778.3	687.1	3.7	1093.5	955.8	173.0
ICI (U.K.)						
1989	$21,591.8	$1524.6[a]	7.1%	$1770.5	$1047.5	133.8
1988	20,816.7	1567.6[b]	7.5	1443.1	1005.3	130.4
1987	18,234.4	1245.9	6.8	1160.7	755.7	127.8
1986	14,862.2	879.8[c]	5.9	942.8	573.3	121.8
Ciba-Geigy (Switzerland)						
1989	$12,565.9	$ 949.4	7.5%	$1211.6	$1265.2	92.6
1988	12,087.0	907.5	7.5	1106.8	1230.8	88.8
1987	10,579.9	738.3	7.0	918.1	1122.8	86.1
1986	8,863.9	645.0	7.3	684.4	903.9	82.2
Rhone-Poulenc (France)						
1989	$11,452.7	$ 641.4	5.6%	$1099.7	$ 662.9	85.6
1988	10,962.1	580.0	5.3	990.1	641.4	79.7
1987	9,344.3	392.7	4.2	830.4	585.4	83.0
1986	7,603.8	289.8	3.8	732.5	426.3	78.0
Enimont (Italy)						
1989	$11,452.7	$ 521.9	4.7%	$1445.5	na	52.7
1988[d]	11,261.1	627.5	5.6	920.1	na	54.7
1987	na	na	na	na	na	na
1986	na	na	na	na	na	na
Norsk Hydro (Norway)						
1989	$ 9,612.9	$ 389.4	4.1%	$1316.8	$ 117.5	32.9
1988	9,206.7	526.7	5.7	1355.2	113.5	39.5
1987	8,086.5	311.0	3.8	1451.0	97.2	39.1
1986	7,341.0	(41.4)[e]	—	1562.7	81.2	43.1
Akzo (Netherlands)						
1989	$ 8,837.8	$ 450.1	5.1%	$ 613.2	$ 426.4	70.9
1988	8,374.2	446.0	5.3	641.4	409.0	71.1
1987	7,652.7	354.6[f]	4.6	539.4	362.1	67.4
1986	6,373.5	366.5[g]	5.7	451.4	304.5	68.4
Degussa (West Germany)						
1989[h]	$ 7,636.7	$ 93.1	1.2%	$ 282.4	$ 224.5	33.7
1988[h]	7,730.1	83.0	1.1	255.3	213.1	32.4
1987[h]	6,510.6	67.2	1.0	230.9	150.0	30.8
1986[h]	5,010.1	53.0	1.1	212.0	108.3	25.0

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
Sandoz (Switzerland)						
1989	$ 7,620.1	$584.1	7.7%	$656.1	$673.2	50.7
1988	6,986.3	521.2	7.5	573.3	624.7	48.0
1987	6,026.2	420.8	7.0	421.5	540.3	44.0
1986	4,645.0	300.6	6.5	306.1	414.4	42.6
Solvay (Belgium)						
1989	$ 6,517.8	$524.6[i]	8.0%	$781.7	$304.6	45.1
1988	6,893.3	410.9[j]	6.0	644.5	293.4	44.3
1987	5,989.8	325.9[k]	5.4	498.3	247.1	45.0
1986	4,842.5	222.3[l]	4.6	517.1	192.6	44.8
Hoffmann-La Roche (Switzerland)						
1989	$ 5,984.1	$519.5	8.7%	$553.7	$865.2	50.2
1988	5,952.3	439.4	7.4	446.6	828.9	49.7
1987	5,171.1	323.5	6.3	348.8	715.8	47.5
1986	4,345.7	231.1	5.3	293.7	623.7	46.5
DSM (Netherlands)						
1989	$ 5,081.1	$488.2[m]	9.6%	$820.8	$188.7	30.0
1988	5,111.6	399.5[n]	7.8	667.7	181.8	28.6
1987	4,422.6	260.6[o]	5.9	431.0	140.4	27.9
1986	3,670.6	198.0[p]	5.4	329.0	91.8	27.3
Montedison (Italy)						
1989	$ 4,140.7	$263.8[q]	6.4%	$636.6	$315.6	22.0
1988[d]	4,077.8	376.3	4.4	457.0	259.8	22.4
1987	10,641.2	436.7	4.1	786.3	290.9	47.9
1986	8,607.6	(46.1)[e,r]	—	570.8	207.9	66.6
BOC International (U.K.)						
1989	$ 3,785.4	$375.9	9.9%	$565.2	$ 89.5	38.4
1988	3,771.4	365.1[s]	9.7	523.5	83.3	38.8
1987	3,211.6	273.4[t]	8.5	362.5	61.5	35.5
1986	2,851.3	10.7[u]	0.4	347.4	55.7	37.7
Nobel Industries (Sweden)						
1989	$ 3,424.5	$214.0	6.2%	$224.7	na	22.2
1988	3,488.1	152.3	4.4	176.3	na	22.1
1987	2,195.6	98.1[v]	4.5	162.9	na	18.1
1986	1,615.5	64.6[w]	3.3	108.3	na	16.3
Courtaulds (U.K.)						
1989[x]	$ 3,121.4	$206.6[y]	6.6%	na	na	24.0
1988[x,d]	2,932.4	197.5[z]	6.7	na	na	20.8
1987[x,d]	2,452.5	180.3[aa]	7.4	na	na	23.7
1986[x,d]	2,038.1	213.0	10.5	na	na	20.6
Schering Group (West Germany)						
1989	$ 3,109.0	$119.7	3.9%	$244.1	$373.4	25.3
1988	2,995.5	89.2	3.0	233.5	358.0	24.7
1987	2,611.7	79.4	3.0	220.0	311.7	24.0
1986	2,148.4	65.0	3.0	117.4	253.9	23.9
Kemira (Finland)						
1989	$ 2,570.7	$ 40.9	1.6%	$374.1	na	16.0
1988	2,207.7	117.4	5.3	345.7	na	14.9
1987	1,942.7	64.4	3.3	644.8	na	13.8
1986	1,322.9	56.6	4.3	231.2	na	11.6

Note: All corporate consolidated sales exclude sales of companies owned less than 50%. a Excludes nonrecurring gain of $208.2 million. b Excludes nonrecurring loss of $78.3 million. c Excludes nonrecurring loss of $63.0 million. d Pro forma. e Net loss. f Excludes nonrecurring gain of $134.6 million. g Excludes nonrecurring gain of $9.5 million. h Fiscal year ends Sept. 30. i Excludes nonrecurring loss of $100.5 million. j Excludes nonrecurring loss of $136.5 million. k Excludes nonrecurring loss of $90.0 million. l Excludes nonrecurring loss of $83.3 million. m Excludes nonrecurring gain of $162.7 million. n Excludes nonrecurring loss of $87.9 million. o Excludes nonrecurring loss of $40.4 million. p Excludes nonrecurring loss of $22.4 million. q Excludes nonrecurring gain of $578.7 million. r Excludes nonrecurring gain of $17.6 million. s Excludes nonrecurring loss of $42.2 million. t Excludes nonrecurring loss of $8.2 million. u Excludes nonrecurring loss of $5.0 million and pretax write-off of $187.7 million. v Excludes nonrecurring gain of $17.8 million. w Excludes nonrecurring loss of $13.2 million. x Fiscal year ends March 31. y Excludes nonrecurring loss of $68.9 million. z Excludes nonrecurring gain of $218.9 million. aa Excludes nonrecurring loss of $19.7 million.

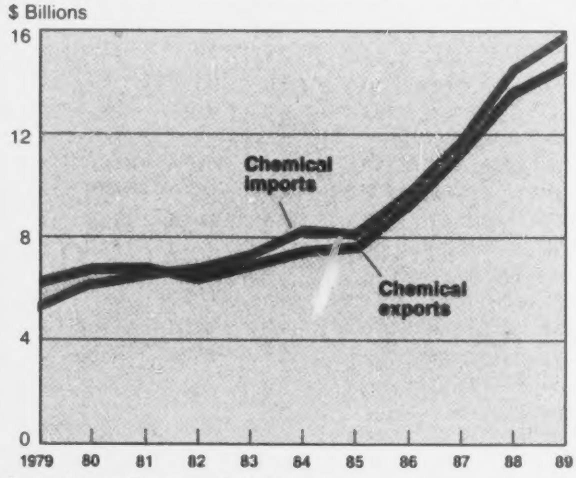
6 Foreign Chemical Industries—Japan

Japanese chemical companies, riding on a buoyant domestic economy, chalked up some impressive results last year. Measured in yen, sales by the chemical industry were up only 4%. Earnings, however, increased a hefty 28%.

The uptrend was particularly strong for petrochemicals, with ethylene output up 11% to 5.6 million metric tons, a new record. Impressive production gains also showed up among several products made from ethylene as well.

On the trade front, however, the record was no way near as rosy. Chemical exports rose 6% but imports increased nearly 8%, driving the country's chemical trade deficit well above the $1 billion level.

Japan's chemical trade deficit increases



Source: Ministry of International Trade & Industry

INDUSTRY TRENDS: Fertilizers continue to slip

Production index, 1985 = 100	1989	1988	1987	1986	Change 1988–89
All manufacturing	120.0	113.1	103.2	99.8	6%
All chemicals	128.0	120.4	111.1	103.2	6
Inorganic chemicals and pigments	114.4	108.4	100.9	98.5	6
Alkalies and chlorine	114.7	110.5	103.6	98.5	4
Organic chemicals	128.1	115.9	105.4	98.5	11
Petrochemicals	129.1	118.1	107.6	100.5	9
Aromatics	133.2	115.9	107.1	99.9	15
Cyclic intermediates and dyes	135.3	121.2	110.9	101.3	12
Plastics	130.7	120.6	109.9	102.5	8
Synthetic fibers	97.5	95.4	94.6	95.9	2
Synthetic rubber	116.7	112.2	102.9	99.6	4
Fertilizer	86.6	88.5	91.6	93.3	−2
Textile materials	118.7	117.8	110.7	103.1	1
Medicinals and drugs	145.0	136.2	123.1	108.8	6

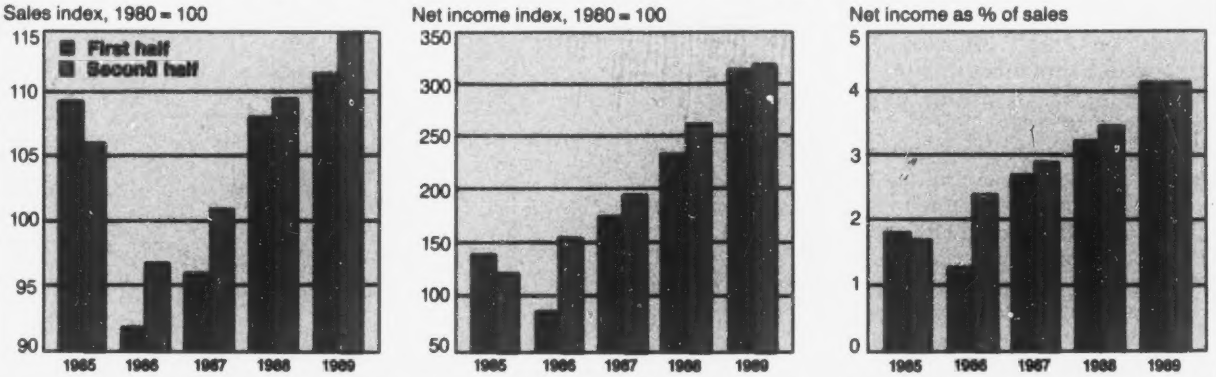
Source: Ministry of International Trade & Industry

PRODUCTION: Strong gains among organics

Thousands of metric tons, unless otherwise indicated	1989	1988	1987	1986	Change 1988–89
INORGANIC CHEMICALS					
Ammonia	1831	1817	1784	1794	1%
Ammonium chloride	274	299	332	364	−8
Ammonium sulfate	1717	1834	1804	1784	−6
Calcium carbide	344	342	354	399	1
Calcium superphosphate	454	476	499	514	−5
Carbon black	779	720	629	616	8
Chlorine, liquid	1009	979	911	881	3
Hydrochloric acid	571	565	543	549	1
Nitrogen, millions of cu m	7856	6940	6452	6293	13
Oxygen, millions of cu m	8384	7707	6878	6786	9
Sodium carbonate	1105	1083	1098	1022	2
Sodium hydroxide	3674	3508	3227	3077	5
Sodium silicate	756	721	664	603	5
Sulfuric acid	6885	6766	6541	6561	2
Titanium dioxide	275	258	238	223	7
ORGANIC CHEMICALS					
Acetaldehyde	356	333	285	254	7
Acetic acid	432	402	377	300	7
Acetone	337	289	260	228	17
Acrylonitrile	611	600	573	546	2
Benzene[a]	2672	2374	2226	2071	13
Butadiene	827	780	707	656	6
Butanol	291	276	259	248	5
Caprolactam	469	493	470	448	−5
Cyclohexane	656	561	557	515	17
Dioctyl phthalate	293	273	261	257	7
Ethylene	5602	5057	4585	4291	11
Ethylene dichloride	2464	2301	2051	1908	7
Ethylene glycol	548	349	313	339	57
Ethylene oxide	681	510	484	489	34
Methanol	82	141	181	221	−42
Octanol	285	273	257	235	4
Phenol	423	358	308	260	18
Phthalic anhydride[a]	160	171	172	163	−6
Propylene	4012	3682	3370	3167	9
Propylene glycol	285	265	236	223	8
Styrene	1990	1757	1559	1417	13
Terephthalic acid	1200	1150	1048	935	4
Toluene	1075	1019	1006	805	6
Toluene diisocyanate	104	96	91	86	8
Urea	810	790	729	778	3
Xylene	2488	1988	1767	1510	25
PLASTICS					
Phenolic resins	375	356	332	313	5
Polyethylene	2712	2380	2182	2066	14
Polypropylene	1719	1559	1406	1333	10
Polystyrene	1997	1891	1735	1598	6
Polyvinyl chloride	1972	1838	1663	1540	7
SYNTHETIC RUBBER	1352	1299	1192	1150	4

[a] Petroleum-based product only. **Source:** Ministry of International Trade & Industry

With sales up slightly but earnings strong, profitability is higher



Note: Based on results of 12 leading Japanese chemical companies: Asahi Chemical, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasei, Mitsubishi Petrochemical, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these companies ends March 31. **Source:** Toyo Keizai Shinposha

COMPANY RESULTS: For Japanese chemical firms, profits generally are up and margins wider

$ Millions	Net sales	Net income	Profit margin	Total assets	Employees (thousands)
Asahi Chemical Industry[a]					
1989	$6377	$241.0	3.8%	$6468	15.1
1988	6384	219.4	3.4	6410	15.4
1987	5357	141.0	2.6	5241	15.6
1986	4351	84.6	1.9	4361	15.9
Mitsubishi Kasei[b]					
1989	$5307	$130.8	2.5%	$6621	8.9
1988	6132	124.9	2.0	6973	8.8
1987	4360	90.4	2.1	6002	8.9
1986	3775	42.0	1.1	5014	8.5
Sumitomo Chemical[c]					
1989	$4363	$145.7	3.3%	$5730	7.7
1988	4341	116.4	2.7	5806	7.7
1987	3609	78.6	2.2	4615	7.7
1986	3085	29.3	1.0	3949	7.6
Takeda Chemical Industries[a]					
1989	$4262	$271.7	6.4%	$5280	10.9
1988	4567	269.4	5.9	5358	10.8
1987	3777	219.6	5.8	4628	10.8
1986	2951	133.6	4.5	3599	10.8
Sekisui Chemical[a]					
1989	$4018	$171.6	4.3%	$3414	5.4
1988	3936	141.4	3.6	2919	5.2
1987	3089	84.6	2.7	2555	5.3
1986	2229	31.0	1.4	1782	6.3
Toray Industries[a]					
1989	$3982	$227.7	5.7%	$5362	9.6
1988	4317	134.7	3.1	5528	10.0
1987	3789	113.5	3.0	4854	10.6
1986	3250	67.1	2.1	3947	11.7
Showa Denko[c]					
1989	$3811	$ 97.1	2.6%	$4455	5.1
1988	3679	71.3	1.9	4299	5.1
1987	2908	38.8	1.3	3881	5.0
1986	2116	22.1	1.0	3163	4.8
Dainippon Ink & Chemicals[a]					
1989	$3407	$ 62.4	1.8%	$3999	6.9
1988	3440	62.2	1.8	4074	6.7
1987	2923	43.7	1.5	3366	6.6
1986	2336	32.8	1.4	2214	6.3
Mitsui Toatsu Chemicals[a]					
1989	$2997	$ 87.3	2.9%	$3963	5.4
1988	3082	83.5	2.7	3936	5.4
1987	2543	43.5	1.7	3004	5.6
1986	2110	23.0	1.1	2599	5.6
Mitsubishi Petrochemical[a]					
1989	$2795	$227.8	8.2%	$4376	3.0
1988	2654	160.0	6.0	3493	2.9
1987	2022	64.7	3.2	2843	2.8
1986	1642	25.7	1.6	2073	2.5
Teijin[a]					
1989	$2217	$154.9	7.0%	$4015	5.7
1988	2438	136.5	5.6	3823	5.8
1987	2167	109.3	5.0	3391	6.2
1986	2039	72.0	3.5	2600	6.4
Hitachi Chemical[a]					
1989	$2023[d]	$ 29.7[d]	1.5%[d]	$1279	5.1
1988	2158	28.2	1.3	1261	5.0
1987	1748	20.7	1.2	1056	4.9
1986	1387	14.1	1.0	891	5.0

Note: Monetary statistics are converted from yen to U.S. dollars on the basis of $1.00 equals: 1989, 137.9 Y; 1988, 128.1 Y; 1987, 142.9 Y; 1986, 166.9 Y. Year-to-year changes in sales, net income, and assets are affected by these fluctuations in the currency exchange rate. a Fiscal year ends March 31. b Fiscal year ends March 31 for 1989 and 1988, Jan. 31 for 1987 and 1986. c Fiscal year ends Dec 31. d Estimated. **Sources:** Toyo Keizai Shinposha and Nihon Keizai Shimbon America Inc.

6 Foreign Chemical Industries—Canada

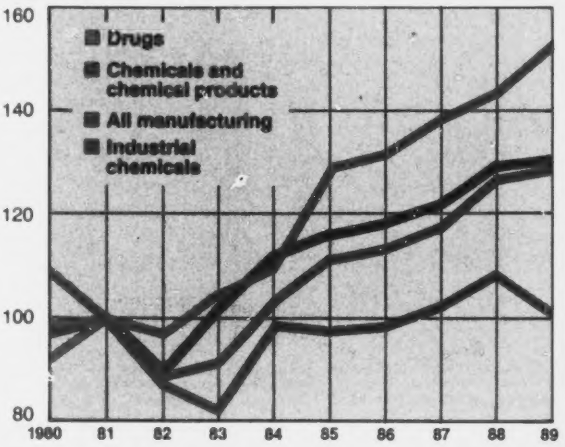
Exports declined and markets were weaker, as well, at home last year, resulting in lower production of many key petrochemicals and some inorganic chemicals in Canada. Coupled with weakness in chemical prices, these factors combined to make 1989 a year that, while still good by past standards, did not measure up to the banner year of 1988.

Canadian chemical companies' profitability felt the impact, as earnings sagged for all the country's major producers. Output was down for such key petrochemicals as ethylene, butadiene, benzene, and methanol. Even the major thermoplastics, which had racked up a long series of annual gains in production, suffered, with low-density polyethylene and polystyrene off 9%, for instance.

Moving into the 1990s, Canadian chemical companies still face many hurdles, not the least of which is an economy made more uncertain by a new Canadian sales tax and, especially, the constitutional impasse that has been threatening to split Quebec off from the rest of the nation.

Only drug output shows strong growth

Production index, 1981 = 100



Source: Statistics Canada

Note on currency conversion: Monetary statistics in this section have been converted from Canadian dollars to U.S. dollars on the basis of $1.00 U.S. equals: 1989, $1.184 Canadian; 1988, $1.231 Canadian; 1987, $1.322 Canadian; 1986, $1.391 Canadian; 1985, $1.362 Canadian; 1984, 1.306 Canadian.

COMPANY RESULTS: **Mixed returns for 1989**

$ Millions (U.S.)	Sales	Net income[a]	Profit margin	Capital expenditures	Employees (thousands)
Celanese Canada					
1989	$ 335.0	$ 40.8	12.2%	$ 14.5	1.9
1988	330.8	39.7	12.0	19.9	2.1
1987	265.5	21.5	8.1	16.1	2.1
1986	248.2	13.5	5.5	9.0	2.1
Du Pont Canada					
1989	$1196.9	$ 66.4	5.6%	$ 91.3	4.1
1988	1119.6	81.2	7.3	86.6	4.0
1987	1021.4	68.5	6.7	47.9	4.2
1986	893.7	43.4	4.9	67.9	4.6
Nova Corp. of Alberta					
1989	$4088.3	$157.1	3.8%	$621.7	13.0
1988	3202.1	321.8	10.0	356.7	11.3
1987	1755.4	170.1	9.7	151.2	7.0
1986	1927.6	96.3	5.0	234.4	6.8
Union Carbide Canada					
1989	$ 436.0	$ 36.0	8.3%	$ 41.7	2.6
1988	461.3	34.3	7.4	45.0	2.8
1987	318.4	19.4	6.1	26.2	2.3
1986	258.1	14.5	5.6	29.7	3.3

[a] Excludes extraordinary gains and losses.

PRODUCTION: **Mostly down last year**

Thousands of metric tons	1989	1988	1987	1986	Change 1988–89
INORGANIC CHEMICALS					
Ammonia	4054	4012	3512	3540	1%
Ammonium nitrate	1056	990	844	948	7
Ammonium phosphate	952	986	941	1149	−4
Carbon black	190	181	249	154	5
Chlorine	1592	1664	1635	1536	−4
Hydrochloric acid	180	180	164	153	0
Nitric acid	1027	919	900	1024	12
Phosphoric acid, 100% P_2O_5	470	475	464	554	−1
Sodium chlorate	593	503	432	373	18
Sodium hydroxide	1542	1720	1770	1696	−10
Sulfuric acid	3560	3805	3437	3536	−6
Zinc oxide	41	62	44	38	−35
ORGANIC CHEMICALS					
Benzene	670	695	720	635	−4
Butadiene	172	182	167	146	−6
Butylene	151	148	156	142	2
Ethylene	2317	2346	2140	1909	−1
Formaldehyde	120	123	122	117	−3
Methanol	2015	2101	1627	1403	−4
Propylene	719	672	628	628	7
Toluene	397	417	396	393	−1
Urea	2402	2372	2142	2330	1
Xylenes	432	399	345	356	8
PLASTICS					
Polyesters, unsaturated	37	43	47	37	−14
Polyethylene, high density	293	311	269	242	−6
Polyethylene, low density	1008	1105	1021	887	−9
Polystyrene[a]	196	216	197	186	−9

[a] Includes acrylonitrile-butadiene-styrene resins. Source: Statistics Canada

SHIPMENTS: Chemicals in general fail to keep pace with other industrial products

$ Millions (U.S.)	1989	1988	1987	1986	1985	1984	Change 1988–89^a
All manufacturing	$250,849	$234,446	$203,013	$182,154	$182,526	$175,834	7%
Chemicals and chemical products	18,588	17,808	15,020	13,401	13,409	13,139	4
Industrial chemicals, inorganic	2,055	1,949	1,780	1,570	1,605	1,757	5
Industrial chemicals, organic	4,567	4,869	3,676	3,128	3,456	3,286	−6
Plastics and synthetic resins	2,165	2,034	1,681	1,488	1,445	1,395	6
Pharmaceuticals and medicinals	2,821	2,528	2,121	1,790	1,637	1,408	12
Adhesives	184	168	150	136	95	94	10
Paint and varnish	1,299	1,220	1,061	894	885	827	6
Soaps and cleansers	1,388	1,239	1,111	1,084	1,002	991	12
Toilet preparations	951	863	759	679	644	616	10
Printing ink	212	208	182	192	177	187	−2
Synthetic fibers	864	791	700	610	572	562	9
Plastic products	4,728	4,401	3,686	3,149	2,834	2,685	7

a In Canadian dollars. **Source:** Statistics Canada

CHEMICAL IMPORTS: Up sharply again

$ Millions (U.S.)	1989	1988	1987	1986
Inorganic chemicals	$1190	$ 910	$ 396	$ 377
Organic chemicals	1646	1559	1270	1163
Fertilizers and fertilizer materials	156	197	158	142
Synthetic and reclaimed rubber	232	228	202	169
Plastic materials	1238	1094	831	702
Plastic film and sheet	427	392	372	306
Other plastic shapes and forms	425	430	261	234
Dyes, except dyeing intermediates	96	86	71	58
Pigments, lakes, and toners	117	115	115	95
Paints and related products	233	195	176	132
Other chemical products	1155	951	857	823
TOTAL	**$6878**	**$6158**	**$4708**	**$4200**
Imports from U.S.	**$5060**	**$4330**	**$3609**	**$3145**
U.S. share	**74%**	**70%**	**77%**	**75%**

Source: Statistics Canada

CHEMICAL EXPORTS: Slightly lower

$ Millions (U.S.)	1989	1988	1987	1986
Chemical elements	$ 171	$ 198	$ 167	$ 173
Other inorganic chemicals	1112	1145	908	881
Organic chemicals	1542	1528	1029	822
Fertilizers and fertilizer materials	1237	1351	960	835
Synthetic rubber and plastic materials	1176	1276	859	631
Plastics, basic shapes and forms	404	383	380	327
Other chemical products	423	380	338	291
TOTAL	**$6063**	**$6262**	**$4639**	**$3961**
Exports to U.S.	**$4026**	**$3927**	**$2938**	**$2625**
U.S. share	**66%**	**63%**	**63%**	**66%**

Source: Statistics Canada

TRADE BALANCE: An unusual deficit . . .

$ Billions (U.S.)	1989	1988	1987	1986	1985
Total exports	$113.0	$109.3	$91.9	$83.9	$85.3
Total imports	114.1	107.0	87.9	81.3	77.1
Trade balance	−1.1	2.3	4.0	2.5	8.2

. . . as gap in chemical trade widens last year

$ Millions (U.S.)	1989	1988	1987	1986	1985
Chemical exports	$ 6063	$ 6262	$4639	$ 3961	$3988
Chemical imports	6878	6158	4708	4200	3997
Chemical trade balance	−815	−104	−69	−239	−9

Source: Statistics Canada

PRICES: Generally somewhat higher

Price index, 1981 = 100	1989	1988	1987	Change 1988–89
All commodities	131.1	128.1	122.8	2%
Chemicals and chemical products	134.8	132.3	120.4	2
Inorganic industrial chemicals	121.5	116.4	111.6	4
Sulfuric acid	135.9	133.6	130.6	2
Chlorine	130.3	130.8	130.4	0
Ammonia	75.7	79.6	78.9	−5
Organic industrial chemicals	116.8	117.0	95.0	0
Benzene-toluene-xylene	87.5	67.5	70.1	30
Olefins	116.9	114.9	79.5	2
Synthetic resins	133.8	141.1	118.0	−5
Polyethylene^a	130.5	146.8	105.6	−11
Polystyrene	132.3	146.4	122.7	−10
Thermosets	138.0	133.0	116.1	4
Synthetic fibers	105.9	103.6	101.7	2
Agricultural chemicals	114.1	112.9	111.8	1
Mixed fertilizers	106.9	107.1	97.9	0
Pharmaceuticals	184.7	177.1	166.9	4
Paint and varnish	144.0	136.3	130.5	6
Soaps and cleansers	138.0	132.4	127.7	4
Toilet preparations	165.3	160.6	152.2	3
Pigments, lakes, and toners	126.4	126.8	120.2	0
Inks	113.1	112.4	110.7	1

a Includes both high and low density. **Source:** Statistics Canada

6 Foreign Chemical Industries—**Eastern Europe**

In 1989, amid political and economic upheaval in East Europe and the Soviet Union, industrial growth there decelerated sharply. Output rose just 1.3% for the region as a whole, according to official statistics, and fell 2% in Hungary and Poland. Output of chemicals also fell in those nations, as well as in Czechoslovakia. Soviet industrial output grew merely 1.7%, the lowest rate since 1950. And chemical production was up only 1.4%. The malaise continues, with Soviet industrial output down 1.2% in this year's first quarter.

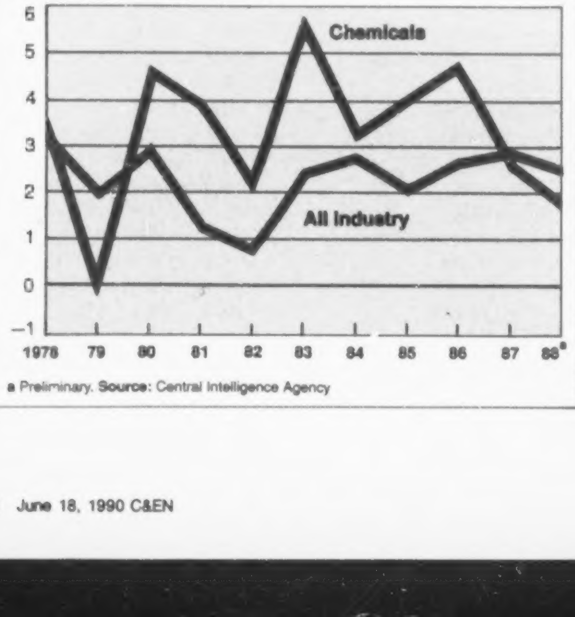
MAN-MADE FIBERS: **Soviet Union accounts for more than half of East Europe's total output**

Production, thousands of metric tons	1988	1987	1986	1985	Change 1987–88
NONCELLULOSIC FIBERS[a]					
Bulgaria	90	88	86	71	2%
Czechoslovakia	140	135	132	115	4
East Germany	168	159	159	146	6
Hungary	26	24	24	23	10
Poland	140	137	132	137	3
Romania	203	202	200	197	1
U.S.S.R.	868	836	758	713	4
TOTAL	**1635**	**1581**	**1491**	**1401**	**3%**
CELLULOSIC FIBERS					
Bulgaria	28	33	42	42	−15%
Czechoslovakia	56	55	55	60	1
East Germany	161	157	158	168	3
Hungary	5	4	6	6	20
Poland	74	73	72	71	2
Romania	76	66	64	62	15
U.S.S.R.	601	592	589	586	2
TOTAL	**1001**	**980**	**986**	**994**	**2%**

a Excludes olefins and glass fiber. **Source:** Fiber Economics Bureau

Growth in industrial output slowed last year in Soviet Union

% annual change in gross output



a Preliminary. **Source:** Central Intelligence Agency

PRODUCTION GROWTH: **A slowdown hits East European industry in 1989**

% annual change in gross output	1989	1988	1987	1986	1985
U.S.S.R. and East Europe					
All industry	1.3	3.8 %	3.7%	4.4%	3.6%
Bulgaria					
All industry	2.2	5.0	4.2	4.0	3.2
Chemicals	2.6	5.0	5.1	4.9	3.6
Czechoslovakia					
All industry	1.0	2.1	2.5	3.2	3.5
Chemicals	−0.2	1.9	3.2	4.0	5.1
East Germany					
All industry[a]	2.3	3.2	3.1	3.7	4.4
Chemicals	na	4.0	2.6	2.2	3.7
Hungary					
All industry	−2.0	−0.7	3.5	1.9	0.7
Chemicals[b]	−3.7	0.3	5.8	1.1	0.8
Poland					
All industry	−2.0	5.3	3.4	4.7	4.5
Chemicals	−1.1	6.5	4.3	4.2	3.0
Romania					
All industry	na	3.6	4.5	7.7	4.9
Chemicals	na	3.0	−4.1	8.3	0.3
U.S.S.R.					
All industry[c]	1.7	3.9	3.8	4.4	3.4
Chemicals[c]	1.4	3.8	4.4	6.3	5.0
All industry[d]	na	2.4[e]	2.9	2.7	2.0
Chemicals[d]	na	1.8[e]	2.6	4.8	4.1

a Industrial commodity production. b For state and cooperative industry only. c Figures based on official Soviet statistics. d Figures based on Central Intelligence Agency estimates, giving lower results because of postulated upward bias in official figures. e Preliminary figure. na = not available. **Sources:** United Nations Economic Commission for Europe and state central statistical bureaus, Central Intelligence Agency, PlanEcon Inc.

AGRICULTURAL CHEMICALS: **Fertilizer supplies fall drastically in Soviet Union**

Thousands of metric tons	1989	1988	1987	1986	1985
Bulgaria					
Fertilizer supply[a]	na	na	745	808	865
Pesticide supply[b]	na	na	28.5	36.5	35.6
Czechoslovakia					
Fertilizer supply[a,c]	na	1,595	1,562	1,780	1,714
East Germany					
Fertilizer supply[a]	na	1,805	1,664	1,642	1,639
Pesticide supply[b]	na	30.1	29.9	29.4	26.7
Hungary					
Fertilizer supply[a]	na	1,418	1,373	1,383	1,338
Poland					
Fertilizer supply[a,c]	3,690	3,277	3,583	3,413	3,280
Pesticide supply[b]	21.0	23.4	18.4	14.5	12.4
Romania					
Fertilizer supply[a]	1,200[d]	na	na	1,386	1,374
U.S.S.R.					
Fertilizer supply[a]	24,100	27,196	27,412	26,514	25,395
Nitrogen[a]	na	11,758	11,787	11,475	10,950
Phosphate[a,e]	na	8,556	8,564	8,354	7,615
Potassium[a]	na	7,044	7,052	6,677	6,822

a Nutrient content basis, as N, P_2O_5, or K_2O. b On basis of active substance. c For year ending June 30. d Approximate value. e Includes ground phosphate rock. na = not available. **Sources:** Department of Agriculture, Central Intelligence Agency, official national statistics from state central statistical bureaus

PRODUCTION: **Output has stagnated for many major chemical products in East Europe**

Thousands of metric tons, unless otherwise noted	1989	1988	1987	1986	1985
U.S.S.R.					
Sulfuric acid	28,300[a]	29,372	28,531	27,847	26,037
Mineral fertilizers[b]	34,300[a]	37,100	36,334	34,737	33,194
Nitrogen[b]	na	15,800	15,743	15,221	14,223
Phosphate[b,c]	na	10,000	9,693	9,279	8,596
Potassium[b]	na	11,300	10,888	10,228	10,367
Synthetic ammonia[d]	na	20,330	19,931	19,590	18,232
Plastics[e]	5,800[a]	5,672	5,488	5,345	5,019
Sodium hydroxide	3,200[a]	3,324	3,288	3,229	3,056
Ethylene	na	3,175	2,977	2,799	2,667
Methanol	na	3,211	3,284	3,219	2,850
Synthetic rubber[f]	na	2,485	2,366	2,320	2,125
Pesticides[g]	na	317	327	332	348
BULGARIA					
Sulfuric acid	770	780	689	807	810
Mineral fertilizers[b]	724	767	571	580	640
Nitrogen[b]	555	588	443	448	469
Phosphate[b]	169	178	128	132	172
Synthetic ammonia[d]	na	1,336	1,070	1,091	1,138
Plastics	na	363	322	420	406
Sodium hydroxide	113	129	104	138	151
Synthetic rubber	na	24	24	25	26
Pesticides[g]	18	15	15	15	18
CZECHOSLOVAKIA					
Sulfuric acid	1,142	1,249	1,264	1,292	1,297
Mineral fertilizers[b]	1,008	1,025	984	1,041	962
Nitrogen[b]	604	596	596	614	526
Phosphate[b,c]	296	313	277	307	310
Potassium[b,g]	108	116	111	120	126
Synthetic ammonia[d]	797	775	781	765	818
Plastics	1,186	1,180	1,152	1,140	1,103
Sodium hydroxide	337	337	344	347	332
Synthetic rubber	76	77	77	76	70
Pesticides[g]	18	19	18	19	19
EAST GERMANY					
Sulfuric acid	na	799	867	883	883
Mineral fertilizers[b]	na	5,192	5,118	5,046	4,842
Nitrogen[b]	na	1,383	1,317	1,252	1,078
Phosphate[b,c]	na	300	291	309	299
Potassium[b]	na	3,510	3,510	3,485	3,465
Synthetic ammonia[d]	na	1,160	1,179	1,197	1,210
Plastics	na	1,149	1,061	1,045	1,048
Sodium hydroxide	na	627	577	638	667
Synthetic rubber	na	104	99	120	158
Pesticides[g]	na	62	59	62	60
HUNGARY					
Sulfuric acid	482	512	573	540	520
Mineral fertilizers[b]	903	921	893	865	864
Nitrogen[b]	na	556	600	584	604
Phosphate[b]	na	228	177	163	130
Potassium[b,h]	na	137	116	118	130
Synthetic ammonia[d]	na	691	787	762	790
Plastics	634	590	545	426	389
Ethylene	262	264	270	269	271
Sodium hydroxide[i]	204	202	197	202	194
POLAND					
Sulfuric acid	na	3166	3149	2965	2863
Mineral fertilizers[b]	2727	2724	2622	2526	2270
Nitrogen[b]	1645	1622	1543	1445	1254
Phosphate[b]	945	962	942	948	889
Potassium[b,h]	137	140	137	133	127
Synthetic ammonia[d]	na	1923	1791	1747	1490
Plastics	723	720	641	632	603
Sodium hydroxide	na	444	422	427	414
Ethylene	na	328	276	279	261
Synthetic rubber	na	127	117	116	126
ROMANIA					
Sulfuric acid	na	na	1693	1971	1835
Mineral fertilizers[b]	2805	2994	2897	3278	3097
Nitrogen[b]	na	na	2080	2315	2197
Phosphate[b]	na	na	760	849	788
Synthetic ammonia[d]	na	na	2784	3037	2876
Plastics	na	654	638	664	628
Sodium hydroxide	na	na	817	846	814
Ethylene	na	na	319	312	307
Synthetic rubber	na	164	152	173	156
Pesticides[g]	na	na	41	53	53

a Approximate figures. **b** Nutrient content basis, as N, P_2O_5, or K_2O. **c** Including production of ground phosphate rock for direct applications and phosphate animal feeds. **d** Nitrogen content. **e** Including resins for man-made fibers. **f** Estimated. **g** On basis of active substance. **h** Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. **i** Including regenerated NaOH. **na** = not available. **Sources:** Central Intelligence Agency, Department of Agriculture, PlanEcon Inc., official national statistics from state central statistical bureaus.

SOVIET FOREIGN TRADE: **Rapid rise in imports switches balance from surplus to deficit**

$ Millions	1989[a]	1988[a]	1987	1986	1985	1984	1983	1982	1981	1980	1979
Exports[b]	$111,361	$110,740	$107,664	$ 97,053	$87,196	$91,495	$91,652	$87,168	$ 79,380	$ 76,437	$ 64,912
Imports[b]	116,862	107,316	95,970	88,874	83,315	80,409	80,445	77,846	73,194	68,473	57,958
Trade balance	−5,501	3,424	11,695	8,179	3,881	11,086	11,207	9,322	6,186	7,964	6,954
Chemical exports[b]	na	na	2,979	2,770	2,837	2,707	2,307	2,203	2,275	2,025	1,606
Chemical imports[b]	na	na	4,516	3,990	3,774	3,256	3,216	3,028	3,211	3,275	2,803
Chemical trade balance	na	na	1,537	−1,220	−937	−549	−909	−825	−1,651	−1,250	−1,197

a Preliminary values. **b** Free on board. **na** = not available. **Sources:** Central Intelligence Agency, U.S.-U.S.S.R. Trade & Economic Council, based on official Soviet statistics and exchange rates.

6 Foreign Chemical Industries—Western Pacific

SOUTH KOREA

INDUSTRY TRENDS: Chemical growth slows

Index, 1985 = 100	1989	1988	1987	1986	Change 1988–89
Chemicals, petroleum, coal, rubber, and plastic products					
Production	154.8	150.7	127.3	111.4	3%
Shipments	152.2	146.3	124.3	110.6	4
Inventories	155.4	128.5	114.0	109.9	21
Industrial chemicals					
Production	156.7	149.4	128.0	111.5	5
Shipments	151.6	146.1	128.2	113.6	4
Inventories	164.6	117.4	106.5	99.2	40
Other chemical products					
Production	182.8	171.2	132.6	108.0	7
Shipments	182.4	166.4	135.1	109.9	10
Inventories	195.4	159.5	122.5	114.0	23
Rubber products					
Production	128.1	151.1	140.0	122.6	−15
Shipments	128.1	150.9	139.2	121.3	−15
Inventories	123.1	131.2	119.4	114.4	−6
Plastic products					
Production	157.1	159.5	137.0	113.9	−2
Shipments	145.8	148.3	132.4	114.4	−2
Inventories	193.5	148.3	141.6	125.6	30
All manufacturing					
Production	170.5	166.1	145.9	121.9	3
Shipments	170.5	164.2	144.6	121.3	4
Inventories	161.6	137.6	120.6	108.6	17

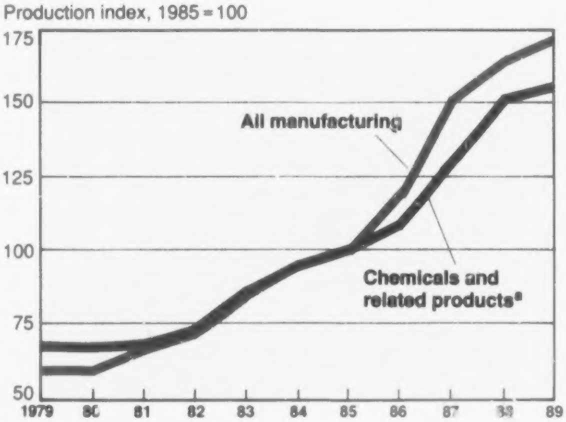
Source: Bureau of Statistics of the Korean Economic Planning Board

FOREIGN TRADE: Surplus shrinks markedly

$ Millions	1989	1988	1987	1986
Exports[a]	$ 62,377	$ 60,696	$ 47,281	$ 34,714
Imports[b]	61,465	51,811	41,020	31,584
Trade balance	912	8,886	6,261	3,130
Chemical exports[a,c]	2,050	1,879	1,321	1,068
Chemical imports[b,c]	7,158	6,282	4,595	3,495
Chemical trade balance	−5,108	−4,404	−3,274	−2,427

a Free on board. b Includes cost, insurance, freight. c Includes chemicals and related products. **Source:** Korean Office of Customs Administration

Surge in South Korea's industrial output eases a bit



a Includes petroleum, coal, rubber, and plastic products.
Source: Bureau of Statistics of Korean Economic Planning Board

PRODUCTION: Plastics up but fertilizers down

Thousands of metric tons	1989	1988	1987	1986	Change 1988–89
Complex fertilizers	1985	2076	2026	1907	−4%
Urea fertilizers	888	1000	911	812	−11
Ethylene	663	609	576	534	9
Polyester fibers	654	593	496	426	10
Polyethylene	637	572	469	376	11
Polypropylene	530	518	348	263	2
Polystyrene	434	341	304	253	27
Polyvinyl chloride	464	455	451	472	2
Propylene	375	351	328	307	7
Benzene	305	308	339	301	−1
Sodium hydroxide	295	311	262	259	−5
Synthetic detergents	297	278	214	169	7

Source: Bureau of Statistics, Korean Economic Planning Board

AUSTRALIA

PRODUCTION: Growth stalls for plastics

Thousands of metric tons	1989[a]	1988[a]	1987[a]	1986[a]	Change 1988–89
Chemicals					
Hydrochloric acid, 100%	64	69	62	54	−8%
Nitric acid, 100%	na	204	203	193	na
Sulfuric acid, 100%	1904	1816	1678	1788	5
Ammonium sulfate	162	179	165	205	−10
Superphosphate[b]	3681	3194	2769	2610	15
Plastics and resins	986	990	904	885	0
Synthetic detergents	316	272	254	239	16
Unsupported plastics film, sheeting	185	188	174	162	−2
Polyethylene[c]	137	139	128	120	−2
Polyvinyl chloride[d]	15	16	16	15	−6

a Year ending June 30. b Includes double and triple superphosphates and ammonium phosphate expressed in terms of single phosphate (22% P_2O_5 equivalent). c Low and high density. d Including copolymers. na = not available. **Source:** Australian Bureau of Statistics

FOREIGN TRADE: Chemical imports up sharply

$ Millions	1989[a]	1988[a]	1987[a]	1986[a]
Exports[b,c]	$ 35,422	$ 29,935	$ 23,745	$ 22,936
Imports[d]	38,411	29,591	24,568	24,253
Trade balance	−2,989	344	−823	−1,317
Chemical exports[b,c]	861	650	440	414
Medicinal products	189	149	110	103
Chemical imports[d]	4,045	3,118	2,304	2,116
Organic chemicals	951	806	584	536
Medicinal products	566	472	337	275
Chemical trade balance	−3,184	−2,468	−1,864	−1,702

Note: Monetary statistics converted from Australian to U.S. dollars on basis of $A1.00 equals: 1986, $0.6996; 1987, $0.6636; 1988, $0.7290; 1989, $0.8160. a Year ending June 30. b Free on board. c Includes reexports. d Values for customs purposes, free-on-board basis. **Sources:** Australian Department of Foreign Affairs & Trade, Reserve Bank of Australia

6 Foreign Chemical Industries—Eastern Asia

CHINA

PRODUCTION: Expansion continues, with plastics and fibers setting the pace last year

Thousands of metric tons, unless otherwise noted	1989	1988	1987	1986	Change 1988–89
Synthetic ammonia	20,675	19,725	19,486	17,195	5%
Fertilizer[a]	18,547	17,670	17,033	13,966	5
Sulfuric acid	11,408	10,981	9,620	7,631	4
Sodium hydroxide	3,212	2,925	2,735	2,270	10
Sodium carbonate	2,983	2,593	2,372	2,150	15
Plastics	1,973	1,552	1,571	1,322	27

Thousands of metric tons, unless otherwise noted	1989	1988	1987	1986	Change 1988–89
Man-made fibers	1,466	1,284	1,157	1,016	14
Synthetic detergents	1,380[b]	1,290	1,192	1,150	7
Ethylene	1,405	1,231	839	642	14
Pesticides	224	202	157	223	11
Pharmaceuticals	196	194	154	107	1
Rubber tires[c]	31,586	29,256	23,328	19,236	8

a Nutrient content. b Estimated. c In thousands of units, not including aircraft and bicycle tires. na = not available. **Sources:** State Statistical Bureau of the People's Republic of China, *China Daily*, *China Economic News*, Central Intelligence Agency

CHEMICAL IMPORTS: Large drop in 1989

$ Millions[a]	1989	1988	1987	Change 1988–89
Organic chemicals	$1405	$1701	$ 998	−17%
Inorganic chemicals	469	448	422	5
Dyeing, tanning, coloring materials	226	237	202	−4
Medicinal and pharmaceutical products	311	384	229	−19
Fertilizers[b]	2364	2335	1399	1
Plastic materials, resins, cellulose esters and others	2206	3558	1470	−38
TOTAL	**$7556**	**$9139**	**$5008**	**−17%**

a Includes cost, insurance, and freight. b Manufactured. **Source:** General Administration of Customs of the People's Republic of China

CHEMICAL EXPORTS: Further increase

$ Millions[a]	1989	1988	1987	Change 1988–89
Organic chemicals	$ 690	$ 575	$ 500	20%
Inorganic chemicals	794	762	553	4
Dyeing, tanning, coloring materials	288	229	175	26
Medicinal and pharmaceutical products	549	466	408	17
Essential oils, perfumes, cleansing materials	235	183	136	29
Explosives, pyrotechnic products	244	298	183	−18
TOTAL	**$3201**	**$2897**	**$2235**	**10%**

a Free on board. **Source:** General Administration of Customs of the People's Republic of China

TAIWAN

INDUSTRY TRENDS: Petrochemicals falter

Industrial production indexes, 1986 = 100	1989	1988	1987	1986	Change 1988–89
All manufacturing	119.3	115.4	111.2	100.0	3%
Chemical materials	110.3	108.0	103.6	100.0	2
Basic chemicals	102.9	94.4	96.5	100.0	9
Petrochemicals	92.9	98.8	97.1	100.0	−6
Fertilizers	111.3	113.4	102.9	100.0	−2
Synthetic fibers	126.7	113.5	109.7	100.0	12
Plastics and resins	126.1	122.8	110.6	100.0	−3
Chemical products	129.1	125.7	114.8	100.0	3

Source: Taiwan Ministry of Economic Affairs

FOREIGN TRADE: Chemical deficit lower

$ Millions	1989	1988	1987	1986
Exports[a]	$ 66,205	$ 60,585	$ 53,612	$ 39,849
Imports[b]	52,267	49,656	34,957	24,165
Trade balance	13,938	10,929	18,655	15,684
Chemical exports[a,c]	5,397	4,844	3,741	2,743
Chemical imports[b,c]	7,410	7,051	5,150	3,870
Chemical trade balance	−2,013	−2,207	−1,409	−1,127

Note: Statistics converted from NT$ to U.S. dollars on basis of $1.00 equals: 1989, NT$26.4; 1988, NT$28.6; 1987, NT$31.8; 1986, NT$37.9. a Free on board. b Includes cost, insurance, and freight. c Includes chemicals, chemical products and plastic and rubber products. **Sources:** Taiwan Council for Economic Planning & Development, Taiwan Ministry of Finance Department of Statistics, C&EN estimates

PRODUCTION: Down for several top chemicals

Thousands of metric tons, unless otherwise noted	1989	1988	1987	1986	Change 1988–89
Polyester[a]	1193	1235	1076	941	−3%
Sulfuric acid	768	664	742	727	16
Ethylene	766	852	823	868	−10
Polyvinyl chloride	805	779	773	724	3
Vinyl chloride	662	708	699	668	−6
Ammonium sulfate	524	484	485	604	8
Compound fertilizer	488	470	420	371	4
Ammonia, anhydrous	246	339	296	323	−27
Sodium hydroxide	186	331	325	366	−44
Hydrochloric acid	217	255	251	242	−15
Urea	237	306	244	214	−23
Calcium superphosphate	352	315	342	336	12
Ethylene glycol	216	197	195	219	9
Oxygen[b]	352	350	261	262	1
Polyethylene	344	390	375	400	−12
Acrylonitrile-butadiene-styrene	311	301	208	151	3
Paints	214	247	229	184	−13
Dioctyl lactam	179	167	192	185	7
Styrene	301	331	310	243	−9
Acrylonitrile	132	144	125	150	−8

a Filament and Fiber. b Millions of cubic meters. **Sources:** Taiwan Council for Economic Planning & Development

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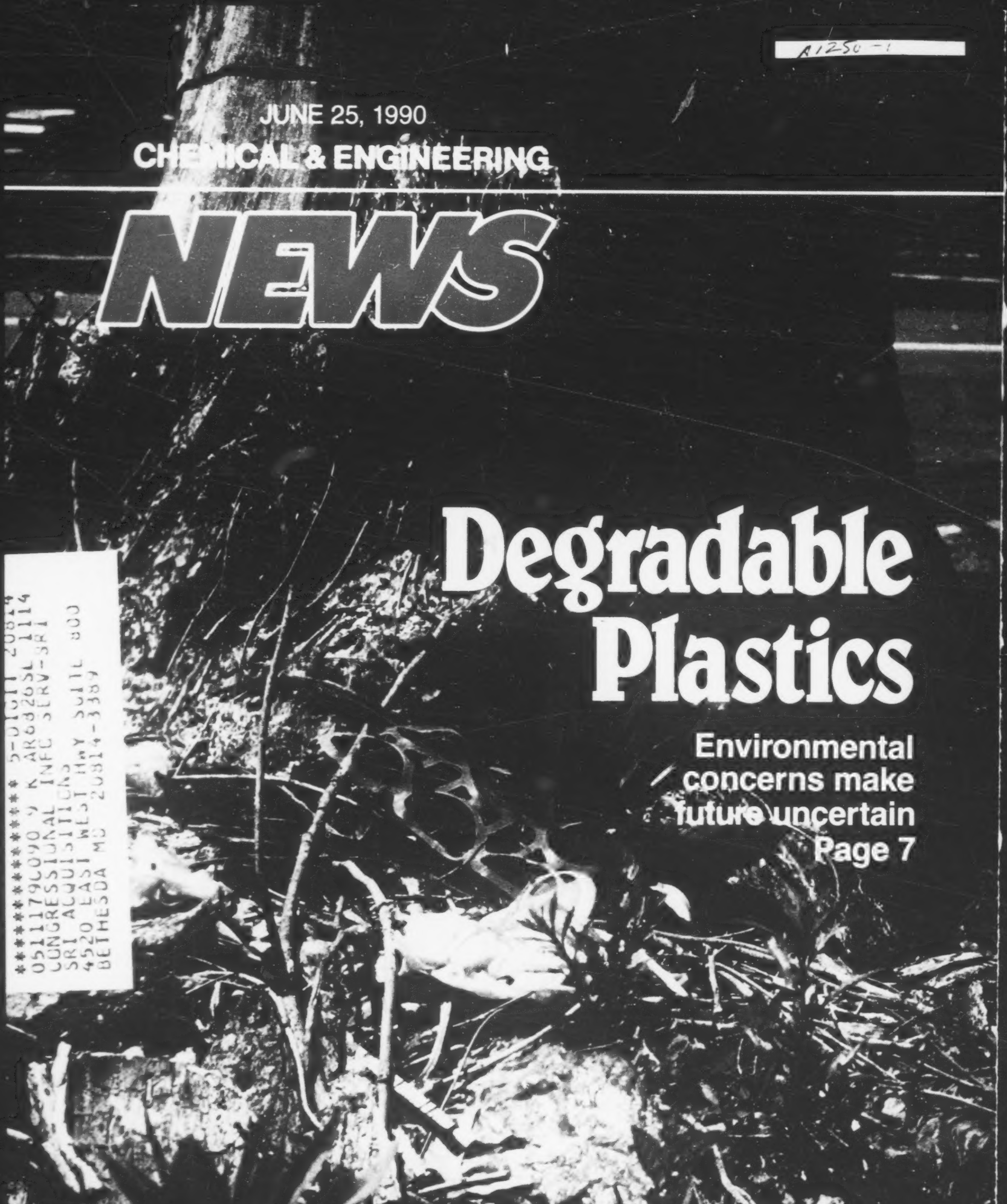
JUNE 25, 1990
CHEMICAL & ENGINEERING
NEWS



Degradable Plastics

Environmental concerns make future uncertain
Page 7

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JUNE 25, 1990

News of the Week

- **Goal of a recent conference organized by a consortium of national organizations and local alliances is to set up a mechanism to coordinate efforts to reform science education.** **Page 4**
- **ACS officials responded strongly last week to the antitrust suit initiated by Dialog Information Services against the society, declaring that there is no truth to the allegations.** **Page 4**
- **U.S., California sue under the Superfund law eight firms for polluting waters, injuring marine life off the California coast.** **Page 5**
- **House hearing on federal aid to schools for removing asbestos raises many questions, reflecting the debate over how big a risk asbestos in buildings poses.** **Page 5**
- **Environmental group urges boycott of household products containing 1,1,1-trichlorethane because of the solvent's potential in depleting atmospheric ozone.** **Page 6**

Cover: Photo by C&EN's Ann M. Thayer

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Business

U.S. chemical industry is wary over trade talks in Geneva, concerned that too much emphasis will be placed on tariff cuts. **Page 17**

Butadiene production probably will be flat or slightly down this year because of sluggish demand for the compound. **Page 19**

Government

Changes in NSF's science education unit have many watching for possible ramifications on efforts to build up science education. **Page 21**

Science/Technology

University of Wisconsin chemists achieve selective bond breaking using isotopically substituted water molecule. **Page 24**

Du Pont inaugurates program to honor the technical achievements of company scientists and engineers. **Page 25**

ACS Comment

Dialog's claims against Chemical Abstracts Service are false and will be repudiated in court, says ACS's executive director, John K Crum. **Page 30**

Meetings

Deadlines and topics for ACS meetings in spring 1991, fall 1991, and later dates are included. **Page 32**

News Focus

Concerns and questions over environmental fate and role of degradable plastics in solid waste management are fostering debate on definitions and standards of new materials and products. **Page 7**

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LETTERS

CHEMICAL SAFETY

Cleaning glass funnels

SIR: The letter by Robert Bergman et al. (C&EN, April 23, page 2) regarding sulfuric acid-hydrogen peroxide mixtures prompts me to offer an alternative technique I have used to clean thousands of fritted glass Buchner funnels, which avoids the storing of such solutions. The item to be cleaned should be freed of as much oxidizable organic matter as practical by mechanical or chemical means then rinsed thoroughly with water to remove any solvents or vapors. Fill a filter flask about one fourth full with water to safely dilute the mixture that drips through. Add sulfuric acid to the fritted item to a depth of one-fourth inch or so. Next add about one-third volume of 30% or 50% hydrogen peroxide and mix well. This should be done in a fume hood. Cover with a watchglass and allow the solution to percolate through the frit. Next add water and allow this to drip through. When using medium, fine, or extra fine frits where liquid passage is slow, the mixture should be allowed to work about 10 minutes, then pulled through with an aspirator vacuum. The item may then be safely rinsed with water and dried with acetone.

The freshly prepared solution when hot is a considerably more efficient cleaner than a cold solution, but the resulting thermal shock may cause some fritted glassware items to crack or break.

I can also recall one instance in which a small amount of liquid acetone (less than 1 mL) was added inadvertently to a freshly prepared sulfuric acid-hydrogen peroxide solution. There was an immediate fire, but there was no explosion. Also be advised that this method will be ineffective for many inorganics or other nonoxidizables.

To the best of my knowledge, sulfuric acid-hydrogen peroxide solutions generate at least some gaseous oxygen when stored, with a resulting decrease in cleaning efficiency.

Thomas Wnuk
Hach Co., Ames, Iowa

***Editor's note:* The following is in "Handbook of Reactive Chemical Hazards" by L. Bretherick, 3rd Ed., page 1160 (1985); and Analytical Methods Committee, *Analyst*, 101, 62 (1976): "Advantages and potential hazards in the use of mixtures of 50% hydrogen peroxide solution and concentrated sulfuric acid to destroy various types of organic materials prior to analysis are discussed in detail. The method is appreciably safer than those using perchloric and/or nitric acids, but the use of an adequate proportion of sulfuric acid with a minimum of peroxide is necessary to avoid the risk of explosive decomposition. The method is not suitable for use in pressure-digestion vessels (PTFE) lined steel bombs, in which an explosion occurred at 80°C."**

Early work with gels

SIR: The report on plastic gels (C&EN, Jan. 8, page 30) by Stephen Stinson describes the "development of useful devices from plastic resins that deform predictably in response to electric fields." It then goes on to state that "such reversible, discontinuous, electric field-stimulated volume transitions were first demonstrated in crosslinked polyacrylamide gels by physics professor Toyoichi Tanaka at Massachusetts Institute of Technology in 1981."

The effect was demonstrated much, much earlier—32 years earlier. I refer to the article by Aharon Katchalsky, "Rapid swelling and deswelling of reversible gels of polymeric acids by ionization" published in *Experientia* [**5**, 319 (1949)] and much subsequent work by Katchalsky with W. Kuhn, H. Eisenberg, and B. Hargitay (and later with A. Oplatka) in which he analyzed the forces producing the volume change, discussed the dynamics, and developed actual devices that used this effect to perform mechanical work on a continuous basis. It might be useful to consult the book "Biophysics and Other Topics: Selected Paper by Aharon Katzir-Katchalsky," Academic Press, New York, 1976, for full references and some reprinted articles.

It is now almost 18 years since Katchalsky was murdered in an indiscriminate terrorist attack on innocent travelers waiting for their baggage at the airport in Lydda, Israel. We still mourn his untimely, senseless death. His work most often put him far ahead of his time.

U.S. Chemical Industry Focuses on Tariffs in Trade Talks

Industry fears that Uruguay round, which is scheduled to be concluded by December, may push tariff cuts and ignore nontariff barriers

Earl V. Anderson,
C&EN Northeast News Bureau

As the Uruguay round of multilateral trade negotiations reaches the make-or-break stage, U.S. chemical trade experts are keeping a wary eye on Geneva, where the trade talks are being held. Once again, as they have in the previous seven rounds of trade negotiations held under the auspices of the General Agreement on Tariffs & Trade (GATT), tariffs loom as a pivotal issue for the U.S. chemical industry.

The Uruguay round, so-named after the country in which it was launched in 1986, has a mandate to tackle a wide range of trade issues. Some, such as agricultural and services trade, foreign investment, and intellectual property rights, are new to GATT. In all, there are 15 groups negotiating trade in goods, plus another group handling the negotiations on services trade.

But despite four years of effort, not one single agreement has been reached yet in the Uruguay round. And now negotiators must face the enormous task of reaching agreement by this December. To meet this deadline, the negotiating groups have been told to lay all their cards on the table by the end of the month.

Many of the chemical industry leaders that shape industry trade policy and funnel advice to the government on trade matters are clearly worried. They are concerned that, in the rush to get everything accomplished, too much emphasis will be placed on reaching a tariff-cutting agreement and too little on accomplishing other things that the industry considers important in the Uruguay round.

Baker: don't offer too much, too early

The Chemical Manufacturers Association (CMA) has labeled several issues as "critical chemical industry issues" in the Uruguay round. CMA says that only by obtaining reasonable results on these issues will U.S. negotiators be able to come home with a balanced, comprehensive agreement. And such an agreement, says CMA, is vital to chemical industry support for the outcome of the Uruguay round.

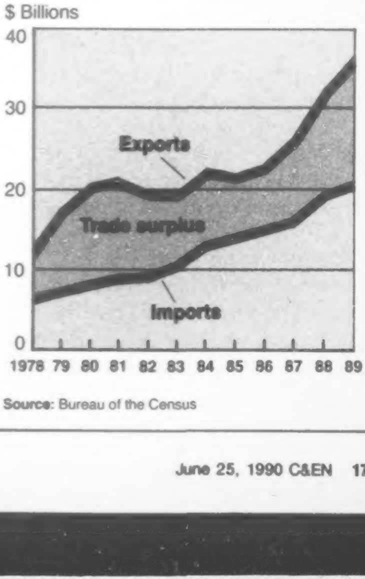
Among the "critical issues" for the chemical industry are TRIPS and TRIMS—trade-related intellectual property (protection) and trade-related investment measures. The industry also is concerned about subsidies and antidumping codes, rules governing "safeguards" against injurious imports, and an adequate GATT dispute settlement mechanism.

But for the U.S. chemical industry, nothing is more important than what is—or is not—done about cutting tariffs. For some time, the industry has hammered home to the U.S. Trade Representative's (USTR) office that tariff-cutting should not be the focal point of the Uruguay round, nor should cuts in chemical tariffs be made in exchange for concessions in nonchemical sectors.

More important, the industry stresses that the tariff negotiations should not be conducted in a vacuum. Instead, they should be linked to negotiations on nontariff barriers to obtain what it calls "equivalent foreign market access." In effect, the U.S. chemical industry wants as easy access to foreign markets as other countries have to markets in the U.S.

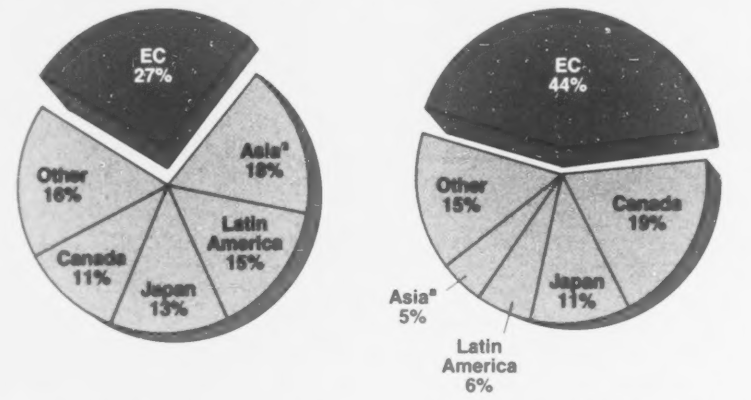
The chemical industry has persistently pointed out to USTR that countries can impede imports with a host of nontariff barriers as well as

U.S. chemical trade surplus continues to grow



Source: Bureau of the Census

European Community is U.S.'s top chemical trade partner



1989 U.S. chemical exports = $36.5 billion

1989 U.S. chemical imports = $20.8 billion

a Excludes Japan and communist countries of Asia

with tariffs. The industry is focusing primarily on the classic "border" nontariff barriers, such as quotas, import licensing fees and other restrictions, stamp taxes, and customs surcharges. GATT rules covering preshipment inspection also are on the chemical industry's "most wanted" list.

The industry also has made it clear to USTR that it will not support an across-the-board, formula approach to tariff cuts in the Uruguay round. Instead, it favors a "request-offer" approach, in which a country makes a specific request to U.S. negotiators, who will then respond with their own tariff-cutting offer.

This is the approach that U.S. negotiators are taking in the Uruguay round. But other countries that already have submitted proposals have based them on fixed percentage, across-the-board (formula) tariff reductions. Proposals that are still to come no doubt will use the formula approach as well.

USTR has indicated that it will stick to its request-offer game plan. But it will accept requests from other countries on either a request-offer or a formula basis. If the proposal is a formula-type tariff cut, USTR will consider tariff cuts only on those items for which the country is the "principal supplier." If U.S. trading partners use a request-offer approach, U.S. negotiators will consider the request entirely, regardless of whether the country is the principal supplier.

However, the prospect of a trading partner submitting a request-offer tariff-cutting proposal in the Uruguay round is remote. And with all other countries taking part in the trade talks negotiating on a different wavelength, the job of the U.S. tariff negotiators becomes very complicated. And there remains the possibility that they could succumb to political pressure to change their tactics.

This possibility is always in the back of the minds of U.S. chemical industry trade experts. And, with the pace of the trade talks heating up, they are concerned about the amount of time they will have to assess tariff-cutting proposals submitted by USTR negotiators. Last month, for instance, industry experts were asked to comment on chemical tariff cuts that the U.S. planned to table at Geneva. USTR gave them one week to do the job. And, because of the Memorial Day holiday, they actually had less time to evaluate the proposals.

These and other chemical industry concerns were aired in a letter that Dexter F. Baker sent to U.S. Trade Representative Carla Hills last month. Baker, chairman and chief executive officer of Air Products & Chemicals and head of the Office of the Chemical Industry Trade Adviser (OCITA), noted the continued USTR assurances that tariff concessions would not be the centerpiece of the Uruguay round and that any U.S. tariff concessions would be linked to and conditioned upon eliminating border nontariff barriers.

However, says Baker, it appears that tariff negotiations will be concluded before private-sector advisers, including those in the chemical industry, will be able to review and assess overall progress in other areas that the chemical industry considers equally important.

OCITA, Baker told Hills, is concerned about the short time that advisers are given to provide advice on possible tariff concessions. And it is concerned about the lack of information on the results that can be expected from Uruguay round negotiating groups. OCITA is a coalition of U.S. chemical trade associations, including CMA, the National Agricultural Chemical Association, the Society of the Plastics Industry, and the Synthetic Organic Chemical Manufacturers Association.

Baker contends that U.S. tariff concessions on chemicals are the best leverage the U.S. has to ensure maximum benefits from other negotiating groups. Therefore, he says, the U.S. should not offer too much, too early. And he urges USTR to consider carefully the advice from chemical-sector trade advisers about import-sensitive products. CMA recently surveyed its member companies, asking them to rate on a scale of one to five the import sensitivity of chemicals that they produce (five is the most import sensitive). The responses included many fours and fives.

Baker emphasizes tariff concessions must be linked to eliminating nontariff barriers to achieve the "substantially equivalent competitive opportunity," which the 1974 trade act mandates. If this is done, and if substantial progress is made on intellectual property and investment negotiations, he says the chemical industry could support the results of the Uruguay round.

This week, Baker will lead a contingent from the U.S. chemical industry to Geneva and other European cities to push the industry's trade position. With a trade surplus of almost $16 billion, the industry has a lot at stake in the Uruguay round. ☐

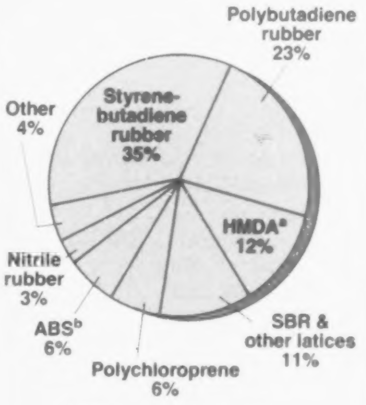
Butadiene is forecast to grow sluggishly

Butadiene growth will be sluggish this year, and pressure on selling prices that developed in May will continue. Despite substantial new ethylene capacity in place, output of butadiene likely will be flat to down a bit for the year, with a slight increase in imports adding to the total supply. Imports for the year will be nudged upward because of a large jump in imports during this quarter. Imports will decline, however, during the second half of the year because U.S. prices will be lower.

Demand for butadiene also will increase only slightly, stemming from lower than normal growth in output of several synthetic rubbers and from low growth in nonelastomer uses. Two synthetic rubbers—styrene-butadiene rubber (SBR) and polybutadiene—account for more than half the butadiene use in the U.S. Both of these rubbers largely are consumed in making tires. U.S. tire production continues to be buffeted by improvements in tire life (which dampens growth in replacement tire demand), by imports of tires, and by lower auto production.

Earlier this year, the International Institute of Synthetic Rubber Producers (IISRP) forecast that rubber use in the U.S. and Canada will grow at 0.7% in 1990 (C&EN, Feb. 5, page 15). Lower demand growth for rubber this year has led to weakening in synthetic rubber prices. Prices of butadiene have followed, declining from 29 cents per lb to 27 cents for June delivery. Speculation is that butadiene prices will slowly decrease later this year because tire demand will be lower during the usual summer slump in auto production.

Butadiene finds large use in elastomers



1989 consumption[c] = 3.58 billion lb

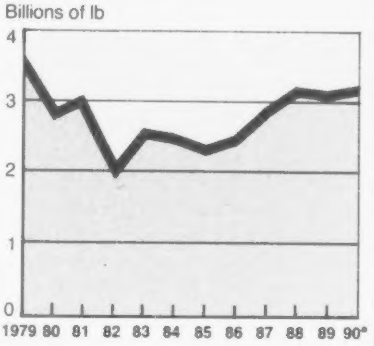
a Hexamethylene diamine b Acrylonitrile-butadiene-styrene. c Excluding exports.
Source: Eugene Debreczeni & Associates

Despite the IISRP forecast for low growth in rubber consumption, consultants Eugene J. Debreczeni of Conroe, Tex., and John R. Hodson of Houston forecast that demand for butadiene will grow 2 to 3% this year, after a decline of about that size in 1989. Consumption will depend on the production of synthetic rubbers in the U.S., which in turn heavily depends on demand for U.S.-made tires. Nontire uses of synthetic rubber may grow faster than tire uses, Hodson says. However, because their bases are smaller, rubber and butadiene demand will be less influenced by nontire than by tire uses.

Production of butadiene could rise faster than demand because of additions to ethylene capacity, Hodson points out. Coproduct butadiene from ethylene manufacture in steam crackers accounted for more than 2.6 billion lb in 1989, or 68% of the U.S. supply of 3.88 billion lb, he says. In 1990, numerous lengthy maintenance shutdowns of steam crackers will reduce output slightly from the 1989 level. However, two large world-scale steam crackers will be started up about the beginning of 1991, increasing the potential supply of coproduct butadiene.

Higher production and lower prices would reduce imports, the second largest source of U.S. supply. Imports of butadiene accounted for nearly 25% of U.S. supply in 1989. About 20% of the total supply, or four fifths of imports, is high-purity or rubber-grade material. The remainder is separated, generally at steam cracker complexes, from imported mixed C_4 hydrocarbons. Because the butadiene is separated at such complexes, and sometimes comingled with the C_4 stream from the steam crackers, it is reported as production by the U.S. International Trade Commission, according to Hodson.

Butadiene production nears former peak



Note: Figures include butadiene recovered at plants processing imported mixed C_4 hydrocarbons. a Forecast.
Sources: U.S. International Trade Commission, C&EN estimate

Consumption of butadiene in 1990 will be about 3.7 billion lb, with an additional 100 million lb being exported, Debreczeni recently forecast. He expects a small quantity to be added to inventory, in contrast to last year, when inventories were reduced.

Butadiene inventories declined from 238 million lb at the end of 1988 to 153 million lb at the end of 1989, according to Charles M. Tucker, a consultant in Dewey, Okla. On June 1, inventories amounted to 197 million lb, Tucker reports. The increase in butadiene inventories of more than 25% this year is another reason for the recent weakening of prices.

SBR and polybutadiene will account for about half the gain in butadiene consumption during 1990, Debreczeni forecasts. These two elastomers will use more than 2.1 billion lb, up 60 million lb from his estimated 1989 consumption. Use of butadiene in making nitrile and polychloroprene rubbers also will be up modestly.

Nonelastomer uses will account for 40% of butadiene growth this year, according to Debreczeni. Use in SBR latexes will grow modestly, up 1.3% to 415 million lb. Most of the remaining consumption growth will be in making hexamethylene diamine for nylon.

Bruce Greek

A1250-1

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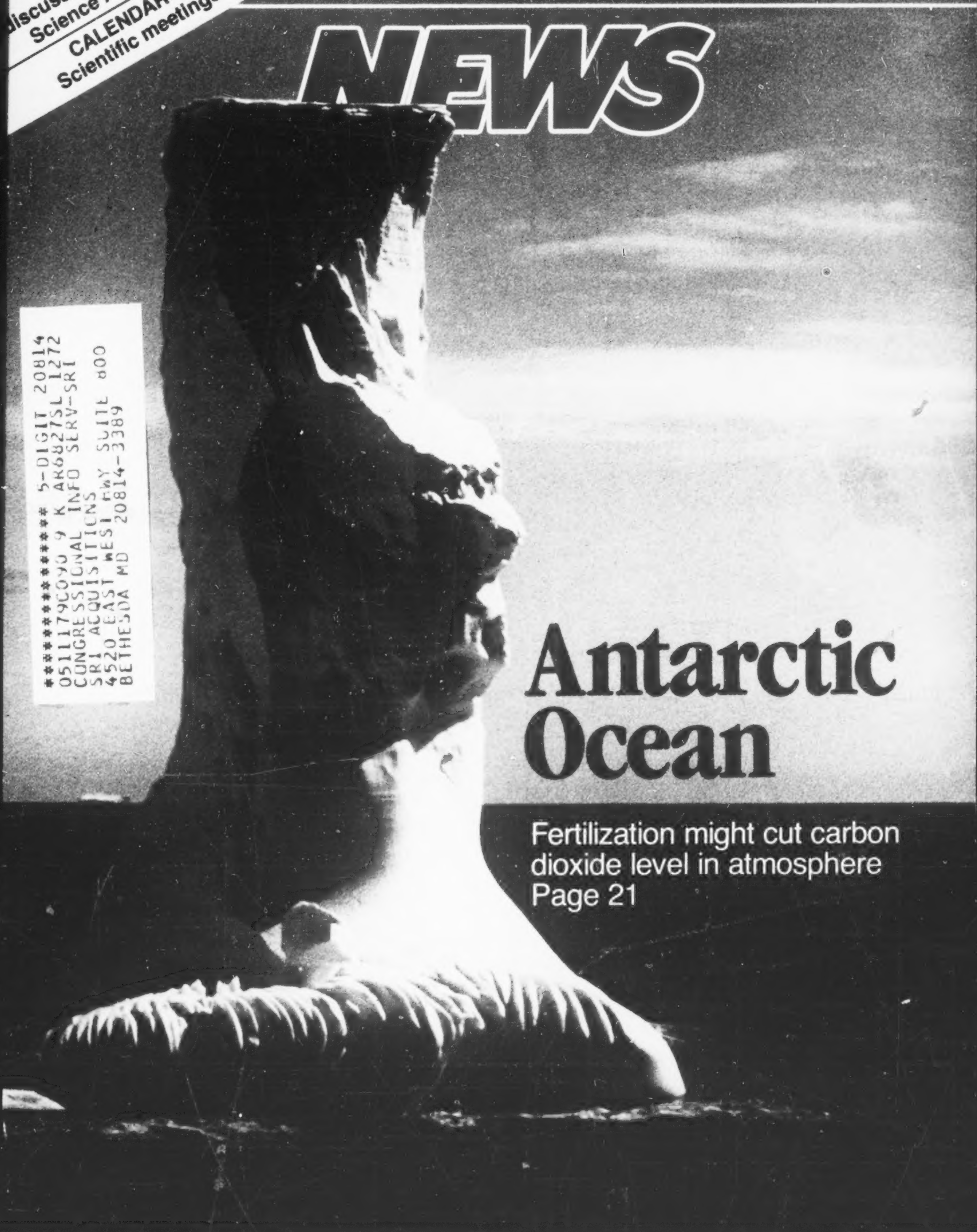

Antarctic Ocean

Fertilization might cut carbon dioxide level in atmosphere
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- **Union launches campaign to establish new set of reforms for chemical plant safety. Page 5**
- **ACS gets 45-day extension for filing initial response to Dialog antitrust lawsuit. Page 5**
- **FDA approves Soviet arrhythmia drug for marketing in U.S. Page 5**
- **West German convicted and sentenced for helping Libya build alleged chemical arms plant at Rabta. Page 6**
- **British firm offers $656 million to acquire ailing Foxboro Co., maker of process control systems. Page 6**

Cover: Photo by Joe Outland/
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Asbestos may pose a risk to another group of workers—building custodians, building renovators or demolishers, and plumbers. **Page 10**

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Herman Bloch, long active in ACS governance activities and former ACS Board chairman, is dead at 78. **Page 36**

Science/Technology

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LETTERS

CHEMICAL SAFETY

Gas occlusion with metals

SIR: William B. Lutz reported (C&EN, May 14, page 2) that when silver was melted in a muffle furnace and poured into a small amount of water an explosion ensued which he attributes to rapid conversion of water to steam by the hot silver.

Probably more to the point is the interaction described in the following quotation from F. E. Matthews [*Encyclopaedia Britannica*, 14th ed., 1940]: "In the molten state silver has the property of 'occluding' about 20 times its volume of oxygen. This . . . is violently ejected on cooling to near the solidifying point, producing a phenomenon known as the 'spitting' of silver. The absorption of oxygen from the air can be prevented by covering the surface either with powdered charcoal or with some nonoxidizing flux."

Gas occlusion can occur with various metals (e.g., hydrogen by cobalt) and should be thought of as potentially hazardous to safety and also to the validity of chemical and physical determinations.

Albert J. Byer
Jamesburg, N.J.

Paper versus plastic

SIR: With the recent celebration of Earth Day and its attendant hype, many suggestions have been made and some actions have been taken to help the environment. I am not sure if all of these have been thoroughly thought out. It seems that some of these actions may be going from a bad thing to something worse.

One action taken at a nearby major university and one that may happen on our campus is to replace polystyrene foam food containers with paper. On the surface this seems to be a good idea, since paper is "natural," though I have never seen paper cups growing wild.

The three big arguments against plastic foam are that chlorofluorocarbons are used in its production, it is made from nonrenewable petroleum, and it is not biodegradable. I looked into the situation. These arguments may not be valid when compared with paper products.

Recent articles state that manufacturers are switching to [hydrochlorofluorocarbons], which are less damaging, or back to the original blowing agent, pentane, which is better, though it is a greenhouse gas.

I found that a paper cup contains a greater mass of wax than the total mass of a polystyrene cup of equal volume. I understand that this wax is low-molecular-weight polyethylene, but even if it is paraffin, it is still a petroleum product. We also must consider the petroleum and coal used for cutting the trees, transporting the logs to the mill, and pulping the paper. There is also pollution from the papermaking process.

Recent studies show that even the "natural" paper products do not degrade in landfills. This may be fortunate since inks and other potential pollutants will not be released from the paper cup.

From my simple analysis, it seems that, except for the HCFCs, polystyrene appears to be at least as good as paper.

One positive aspect to polystyrene cups, since they contain mostly polystyrene, is that they are recyclable, whereas the paper cups are a heterogeneous mixture, complicating recycling.

Most of my work has been from simple experiments and commonly available sources, without the benefit of an inside view. I ask the readers of C&EN, particularly those in the two industries involved, to give us a full analysis of pollution and energy use in the making and marketing of these products from source to disposal. Then we can make an informed choice, rather than having to base our decisions upon partial information. The current situation often leads people to respond to environmental problems with emotional knee-jerk reactions, which may often be incorrect.

I feel that a responsible reporting of the relative merits in this and other situations would do much to help improve the image of chemistry and chemists. I also feel that this type of analysis should be done and made available for all products.

Michael Chejlava
William Jewell College
Liberty, Mo.

Priestley Medal address

SIR: I share Roald Hoffmann's concern expressed in his Priestley Medal address (C&EN, April 23, page 25) about the still rampant spread of chemophobia, and the lack of the public's technical knowledge also mentioned in his previously published remarks (C&EN, Jan. 29, page 28).

I, too, ask why showbiz celebrities like

Chemical Productivity Rose in First Quarter

Productivity in the chemical industry, that nebulous measure of industry health in managing people and ultimately in competitiveness, rose slightly in the first quarter. This rise comes after six quarters of falling or flat productivity indexes.

As chemical industry output slows, it is to be expected that managers will be slower in terms of controlling employment levels. And this time around, this does continue to be the case—at least for the broad chemicals and allied products category. However, they may have caught up to the situation, matching employment levels with the work to be performed.

Granted, if one were able to divine productivity in some of the subgroups of chemicals and allied products—especially some commodity industrial chemicals—one might find a different picture. Overall, however, productivity is up on both a quarter-to-quarter and a year-to-year basis.

Using production data from the Federal Reserve Board and employment figures from the Labor Department, C&EN estimates that labor productivity for the chemical industry in the first quarter increased 1.2% over the fourth quarter of 1989. Productivity is defined as output per hour of production, calculated by dividing the government's index for production by the index for aggregate hours of production. In the fourth quarter of last year, productivity had declined 0.4% from the previous three months.

The first-quarter increase came on both an increase in production and a modest decline in workhours. Chemical output for the quarter showed an average increase of about 1.0% over the prior three months and workhours fell a slight 0.2% during the period.

On a year-to-year basis, production was up 2.1% from the first quarter of 1989, and workhours, while increasing, rose only 1.7% from the same three-month period in 1989. The result was that productivity increased 3.0% in the first quarter from the same period 12 months earlier. In the fourth quarter, chemical labor productivity had been down 1.0% from the same period a year earlier.

By way of contrast, chemical productivity growth was equal to that of all manufacturing on a quarter-to-quarter basis in the first three-month period this year, but was slightly behind when compared with the year-earlier quarter. Labor productivity for all manufacturing was up 1.2% for the first quarter from the final three months of 1989 and up 3.2% from the same period a year earlier.

Chemical unit labor costs also reversed a five-quarter trend in the first three months of this year by falling 1.2% from the fourth quarter of 1989, although this measure is still 2.5% above the year-earlier quarter. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for hourly wages by indexes for output per workhour or productivity. In the fourth quarter, unit labor costs for chemicals and allied products were up 1.5% from the previous three months and up a hefty 4.2% from the same period a year earlier.

The improvement in unit labor costs on a quarter-to-quarter basis in the early part of this year was almost solely the result of the improvement in productivity. While this was increasing 3.0%, hourly production wages were essentially flat, falling a slight 0.1%.

For all manufacturing, unit labor costs were down 0.6% in the first quarter both from the previous three months and from the year-earlier quarter. In the fourth quarter, they had been flat from the July to October period of 1989, but up a meager 0.4% from the fourth quarter the year before.

The improvement in unit labor costs for all manufacturing in the first quarter from the previous three months came mainly from the 1.2% growth in productivity. Hourly production wages in the same period rose 0.7%.

William Storck

Chemical productivity has been relatively flat

	Quarter, 1990	Quarters, 1989				Quarters, 1988			
Indexes, 1987 = 100	1st	4th	3rd	2nd	1st	4th	3rd	2nd	1st
CHEMICALS & ALLIED PRODUCTS									
Production	110.0	108.9	108.9	108.3	107.7	107.1	107.5	104.5	102.4
Workhours	107.5	107.7	107.3	106.7	105.7	104.9	104.0	103.2	102.5
Productivity	102.3	101.1	101.5	101.5	101.9	102.1	103.3	101.3	99.9
Hourly production wages	107.2	107.3	106.1	104.8	104.1	103.9	102.6	101.7	101.3
Unit labor costs	104.8	106.1	104.5	103.3	102.2	101.8	99.3	100.4	101.4
ALL MANUFACTURING									
Production	109.2	108.7	108.9	109.3	108.6	107.7	106.7	105.1	103.7
Workhours	101.0	101.8	103.2	103.7	103.8	103.3	102.7	102.3	101.6
Productivity	108.1	106.8	105.6	105.4	104.7	104.3	103.9	102.7	102.1
Hourly production wages	107.6	106.9	105.8	105.2	104.8	104.0	102.8	102.4	101.6
Unit labor costs	99.[illegible]	100.1	100.2	99.9	100.1	99.7	98.9	99.7	99.5

Note: Productivity is output per workhour, calculated by dividing production index by index for aggregate weekly hours of production. Unit labor costs are costs per unit of output, calculated by dividing index for hourly production wages by that for output per workhour. **Sources:** Federal Reserve Board, Department of Labor, C&EN estimates

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in drug research Page 9

FINAL PROGRAM
ACS national meeting in
Washington, D.C. Page 43

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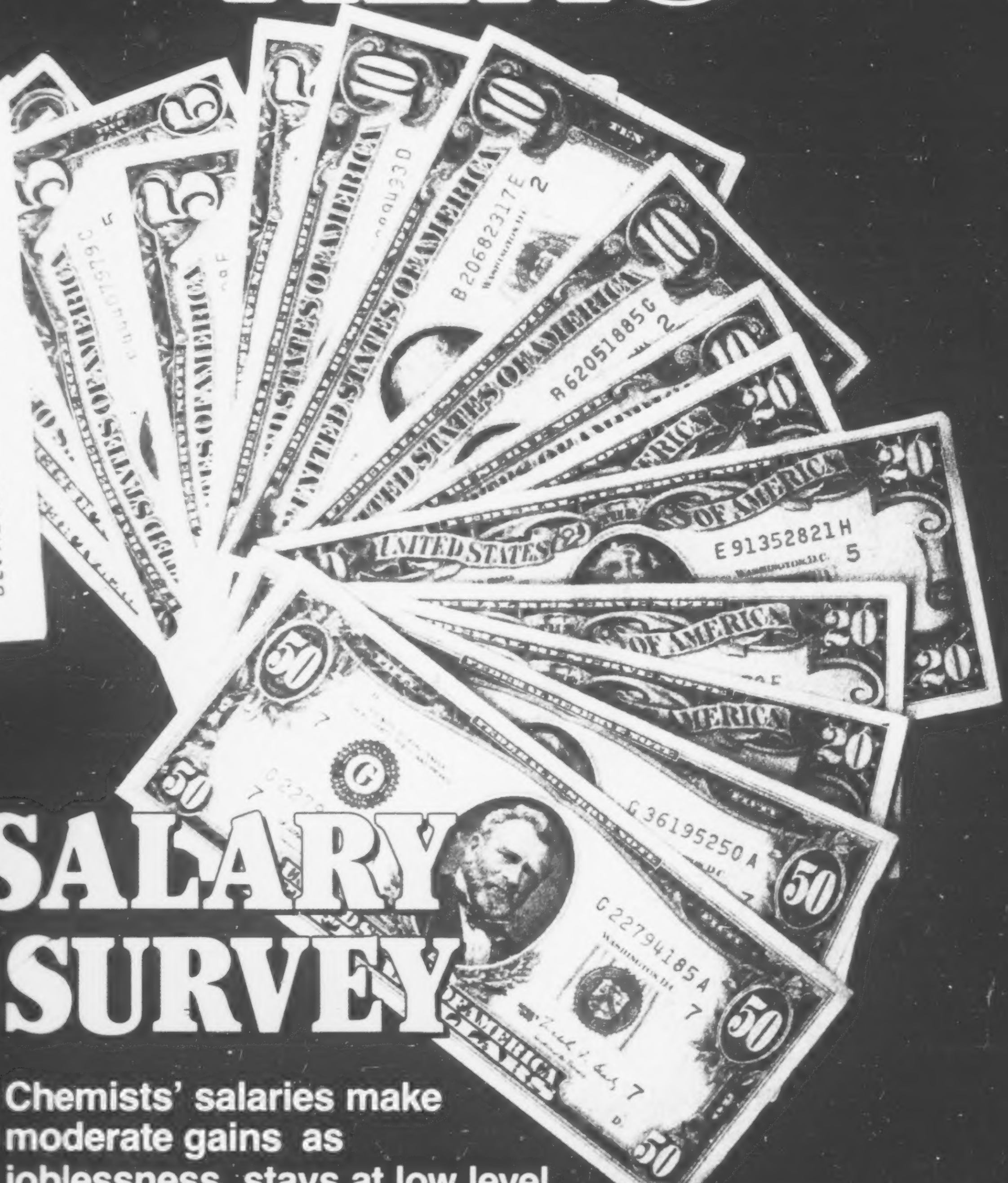

SALARY SURVEY

Chemists' salaries make moderate gains as joblessness stays at low level
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News of the Week

- **Ministers from nearly 100 countries at recent UN-sponsored meeting agree to actions to stem ozone depletion, including setting up a fund to aid developing nations in their use of alternative chemicals, technologies. Page 6**
- **Paint makers voluntarily agree to stop mercurial biocides use in interior latex paints. Page 7**
- **Cost projections for Department of Energy cleanup of its nuclear arms complex will be higher than originally estimated. Page 7**
- **Federal Trade Commission announces it is contesting two chemical acquisitions. Page 8**
- **Georgian Democrat, Sen. Sam Nunn, calls on colleagues to employ defense establishment's know-how in efforts to help halt the destruction of the environment. Page 8**

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200th ACS national meeting in Boston in August will consist of more than 4000 papers, numerous social events, and an exposition. **Page 43**

SALARY
SURVEY

Salary Survey

The unemployment rate for U.S. chemists, at 1.1% last March, remains low for the fourth year straight, ACS survey shows. Median salaries, meanwhile, are 5% higher than a year earlier, about in line with inflation. Page 37

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LETTERS

CHEMICAL SAFETY

Methylene chloride extraction

We would like to relate a potentially hazardous experience involving solvent extraction of water samples using separatory funnel technique. The procedure involved a methylene chloride extraction for the determination of PCBs in water samples and is similar to an incident reported by R. E. Kelling (C&EN, April 30, page 2).

Specifically, two occasions occurred where the glass stopper of the 2-L separatory funnel was violently ejected. The first episode occurred immediately following the addition of 60 mL of methylene chloride to a 1-L sample of water (pH approximately 6). The funnel was placed upright in a ring stand with the stopper inserted and swirled once in the upright position. Before any shaking or inverting, the glass stopper was violently shot upward. This occurred in a hood and fortunately resulted in no injuries.

The second incident involved a similar ejection of the glass stopper from the separatory funnel. This time, however, it occurred several minutes after proper extraction procedure had begun. This time the glass stopper struck the student in the arm and side with enough force to cause a significant bruise—and she was holding the stopper in place with the palm of her hand!

We were carrying out published procedures (EPA method 608) for the environmental analysis of water samples and no unusual events or circumstances were noted that would account for our experiences. Given the similarity of the hazards recently reported for methylene chloride extraction, it is urged that extreme safety precautions be taken when performing these types of experiments.

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Magic or science?

Gordon Barrow, in his letter (C&EN, April 9, page 2), is correct in his observation that a root of the sorry state of chemical education is the general chemistry course, and that only radical change will remedy the present "well-entrenched, ineffective presentation." I recently ran across a telling example of just what's wrong. The authors of an article discussing significant figures presented two alternative procedures. They then opted for the one that by their admission was more arbitrary and harder to justify, even to students, on the basis that "many students (especially at the freshman level), are not yet capable of this level of understanding (or cannot be motivated to achieve it) and must necessarily memorize magic formulas."

How have we come to be teaching magic, rather than science? Because magic is easier. It meets the goals of both students and teachers. To most of our students, chemistry is just part of a professional initiation ritual. They want a set of incantations that will get them an acceptable grade. This is what they've always gotten, under the title of "higher reasoning skills"—the current slogan for slighting the fundamentals. They certainly don't want rigor or uncertainty. Most of their teachers are likewise addicted to the status quo. They want what gets them back to their labs and grant applications with the least fuss or threat to their standing on the student popularity polls titled "teaching evaluation instruments." Especially to be avoided is anything hard enough that it brings students to their offices! Text authors and publishers can't be blamed if they give both teachers and students what they want.

The general chemistry course we badly need is one that attempts far less, and does it far better. If our typical student is unprepared to handle the math of, for example, relative precision, how can that student understand the second law of thermodynamics? We've got to quit supplying answers until students can understand the questions. We need to cover less, so that we can uncover, and our students can discover, a lot more. Some of them may then choose chemistry as a career for the only right rea-

As Unemployment Stays Very Low, Salaries Improve Moderately

The economic well-being of U.S. chemists appears basically favorable this year. Salaries continue to rise at a moderate clip. And as of last March, only 1.1% of chemists were without a job but looking for one, the annual survey of the economic status of U.S. members of the American Chemical Society indicates.

That makes 1990 the fourth year running that unemployment in the profession has hovered close to 1%, the longest such streak of low-level joblessness since ACS began collecting data of this type in 1971. Like last year, moreover, the rate of unemployment is about the same for chemists across the board, whether they are men or women, whatever their highest academic degree, and whether or not they are members of a racial minority. And this year's rate is considerably below the 5.2% unemployment rate last March for the U.S. civilian labor force as a whole, or even the 1.8% rate for all managerial and professional employees.

About half the chemists unemployed but seeking jobs last March report that they place no restrictions on their search for new work, but about a fourth note that their inability to relocate limits their success; other restrictions, such as family responsibilities or the need for part-time work, affected relatively few. Of the 1.4% of chemists employed only part-time, more than a third are doing so out of choice. Family restraints limit an additional 23% to part-time work.

Some other highlights from this year's survey, which also are in line with findings of previous surveys: Chemists working in private industry tend to earn more than their colleagues in the academic world or in government, with the highest base salaries going to those who have managerial responsibilities; the gap between men's salaries and those earned by women persists essentially unchanged; chemists are satisfied by and large with what they are paid, with their opportunities for promotion, and with their jobs in general.

Growth in salaries earned by chemists continues to be moderate. The median base salary at all degree levels, as of March 1, is 5% higher than the median reported last year. (The median is the salary that is exceeded by 50% of the survey respondents; because it is not affected by a few extremely high or low cases, the median reflects more accurately than the mean the typical salary for a given group of individuals.) The annual rate of increase in salaries

Employment differs little among ACS members whatever their gender, education, or background

	Chemists									
		By sex		By highest degree			By minority status			
Employment status[a]	Total	Men	Women	B.S.	M.S.	Ph.D.	Minority[b]	Nonminority	Chemical engineers	All members[c]
Employed full time	94.1%	95.1%	89.8%	95.6%	95.3%	93.2%	91.6%	94.4%	95.4%	94.2%
Employed part time	1.4	0.9	3.8	1.5	1.8	1.3	0.9	1.5	1.6	1.5
Postdoctoral or fellowship	2.2	2.1	2.8	0.1	0.1	3.8	5.6	1.9	0.5	2.1
Unemployed										
Seeking employment	1.1	1.1	1.2	1.2	1.2	1.0	1.2	1.1	1.0	1.1
Not seeking employment	1.1	0.8	2.4	1.7	1.6	0.8	0.6	1.2	1.5	1.2

a As of March 1, 1990. **b** Black, Spanish/Hispanic, American Indian, Alaskan native, Asian, Pacific Islander, or other. **c** Includes ACS members whose highest degree and present work are in neither chemistry or chemical engineering. **Source:** ACS survey

Rate of growth for chemists' salaries held steady during the past decade

											Annual change		
$ Thousands	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1985–90	1980–90
CHEMISTS' MEDIAN SALARIES[a]														
B.S.	$39.0	$37.0	$35.4	$33.5	$33.0	$32.0	$30.9	$30.0	$28.5	$27.5	$25.0	5%	4%	5%
M.S.	45.0	43.0	41.0	39.0	37.9	36.0	34.0	33.0	31.6	30.0	26.0	5	5	6
Ph.D.	55.0	52.5	50.0	47.7	47.8	44.0	42.0	40.0	37.5	35.0	31.2	5	5	6
All chemists	49.8	47.3	45.0	42.5	42.5	40.0	38.0	36.0	34.7	32.0	28.9	5	4	6

a Base annual salary of chemists employed full time as of March 1. **Source:** ACS survey

Salaries increase more moderately for chemists during the latter part of their career

Median salary ($ thousands)[a]	Years since B.S. degree 0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
NONACADEMIC CHEMISTS											
B.S.											
90%	$34.0	$35.5	$44.0	$54.0	$64.0	$71.0	$ 75.0	$ 80.0	$ 82.0	$ 96.0	$64.0
75%	30.0	32.0	38.9	46.8	52.1	60.0	63.0	65.0	66.0	73.0	50.0
50%	27.0	28.6	34.0	40.0	44.0	49.0	51.5	55.0	55.0	58.0	39.0
25%	23.5	25.0	29.5	34.0	37.0	40.2	42.0	45.0	44.2	46.4	31.2
10%	20.0	22.0	25.3	29.5	32.0	34.5	33.5	37.0	36.9	36.0	26.0
M.S.											
90%	—	36.5	45.0	55.5	63.0	70.1	79.0	80.0	81.5	90.0	70.0
75%	—	35.0	40.0	49.0	55.0	61.0	65.0	68.4	70.0	72.8	57.0
50%	—	33.0	36.0	42.5	47.0	51.0	54.0	57.0	59.0	62.0	46.0
25%	—	29.4	32.0	37.2	40.0	43.0	45.2	46.2	47.1	50.0	38.0
10%	—	25.0	27.8	32.0	35.0	36.0	38.9	38.3	40.0	40.0	32.0
Ph.D.											
90%	—	—	52.5	63.0	75.0	87.0	100.0	103.0	110.0	105.0	88.0
75%	—	—	49.8	57.0	65.0	74.2	80.5	84.0	88.0	85.1	72.0
50%	—	—	46.5	51.0	58.0	63.5	68.4	70.0	73.0	72.0	60.0
25%	—	—	43.5	46.2	51.0	54.8	58.0	59.1	60.0	60.0	50.0
10%	—	—	40.0	42.0	44.0	47.0	49.0	50.0	51.0	50.0	44.0

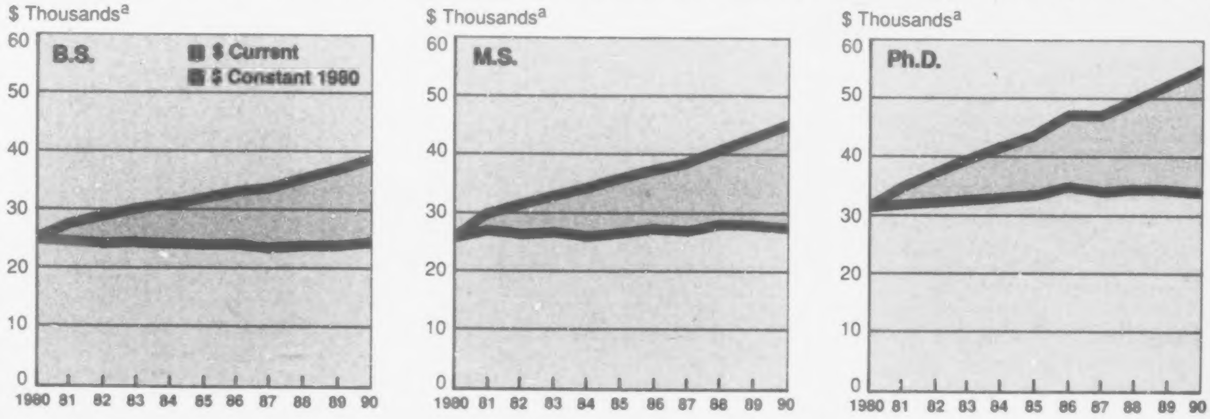
How to read this table: Using, as an example, nonacademic B.S. chemists two to four years after they have received their B.S. degree, 90% of these chemists have annual base salaries of $35,500 or less, 75% have annual base salaries of $32,000 or less; 50% have annual base salaries of $28,600 or less, 25% have annual base salaries of $25,000 or less, and 10% have annual base salaries of $22,000 or less, as of March 1, 1990. a As of March 1, 1990. **Source:** ACS survey

has averaged about the same for more than a decade.

As has been true throughout the 1980s, however, the increase in these medians has done little more than keep pace with the rise in consumer prices. After adjustment for inflation, in fact, the median salary for chemists whose highest degree is a B.S. is 3% lower than what it was 10 years ago. Those with graduate degrees are a little better off, but not much; in constant dollars, the median for chemists with an M.S. is up 8% from 1980, that for chemists with a Ph.D. is 10% higher. Even so, chemists' salaries have fared better during the past decade than they did during the 1970s, when, after factoring in inflation, they actually fell significantly.

The overall median, of course, provides only a very rough measure of typical salaries. What individuals actually earn depends also, for example, on the length of their career, the type of work they do, and whom they work for. When length of career is considered, individuals are likely to have more to show in terms of inflation-adjusted earnings than the overall medians might suggest. Thus, if they earned at the median, recently graduated Ph.D. chemists in nonacademic jobs five years ago would have had a salary of about $38,000. This year, the median for these Ph.D. chemists, now after five additional years of experience, is

Although chemists' salaries keep rising, the increases have been largely offset by inflation



a Median base annual salary for chemists employed full time as of March 1 of each year. **Source:** ACS survey

Salaries are highest for Ph.D. chemists in the oil industry

Industry	% of industrial chemists				Mean salary ($ thousands)[a]		
	All chemists	B.S.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Petroleum and natural gas	4%	4%	4%	5%	$48.4	$56.5	$71.3
Pharmaceuticals[b]	19	17	21	19	44.0	52.1	69.8
Electronics	4	3	3	4	45.6	51.8	67.2
Biochemical products	2	1	2	2	42.8	51.2	66.8
Plastics	5	4	5	6	45.6	53.8	66.3
Food	3	4	4	3	43.4	51.8	65.6
Basic chemicals	6	4	5	8	45.9	53.5	65.6
Specialty chemicals	15	14	13	17	44.8	52.9	64.8
Agricultural chemicals	4	3	4	5	41.7	48.7	63.6
Soaps and detergents	1	2	1	1	45.9	53.3	63.5
Aerospace	3	2	3	3	46.8	54.4	63.3
Metals and minerals	2	3	2	1	40.7	50.6	62.2
Coatings and ink	4	6	5	3	44.5	51.6	61.2
Rubber	2	3	2	1	44.8	53.3	60.5
Paper	1	1	1	1	42.1	56.8	60.4
Other manufacturing	13	14	13	12	42.2	53.2	65.1
Nonmanufacturing	11	15	13	9	43.4	52.7	63.4

a As of March 1, 1990; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. b Includes personal care products. **Source:** ACS survey

$51,000. After adjustment for rising prices during the past five years, that amounts to a real increase of 11%.

Gender continues to be a factor in the level of chemists' salaries. One reason is that women, as a group, tend to be less experienced than men as a group. Nearly half the men chemists working in industry received their B.S. degree 20 or more years ago; only about a fifth of the women did so.

Even when salaries are adjusted for differences in age distribution between the two sexes, however, men have a distinct salary advantage. Men's average salaries (the average rather than the median is used in making the age adjustment) are roughly 10 to 20% higher than the average for women, whether the comparison is between chemists working in industry or academia, for the government, or elsewhere—although the gap is narrowest for government employees. The gap, moreover, has shown no sign of closing appreciably in recent years.

Also as in the past, the difference between men's and women's salaries is slight among chemists who are relatively early in their career—about 5% or less for chemists employed in industry who obtained their B.S. less than 10 years ago. But it widens appreciably for more experienced chemists. The median salary for

Chemists teaching in Ph.D.-granting departments have higher salaries

Median salary ($ thousands)[a]	Years since B.S. degree								
	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
PH.D. CHEMISTS EMPLOYED FULL TIME IN ACADEMIA									
Ph.D.-granting departments									
Professor	—	($ 64.1)	$ 65.1	$ 68.8	$ 72.0	$ 73.2	$ 73.2	$ 77.2	$72.5
Associate professor	—	48.8	51.2	51.2	52.0	52.5	51.4	52.0	51.2
Assistant professor	$ 42.7	42.7	42.0	44.5	—	—	—	—	42.5
Instructor or lecturer	(27.8)	(34.0)	36.0	(39.6)	(40.8)	(45.0)	(43.9)	—	35.0
Research associate	24.9	33.0	40.0	45.0	40.0	(39.0)	(57.1)	—	35.0
All ranks[b]	37.8	42.5	46.6	56.9	64.8	68.0	69.5	73.3	57.1
Non-Ph.D.-granting departments									
Professor	—	—	48.8	52.5	54.9	59.8	58.6	62.2	57.1
Associate professor	—	40.3	41.6	44.5	44.2	48.5	50.0	(45.7)	44.0
Assistant professor	34.2	36.6	36.6	37.0	36.6	(41.2)	—	—	36.5
Instructor or lecturer	(33.2)	(31.1)	(35.5)	(34.5)	(33.4)	—	—	—	34.0
Research associate	—	33.6	(31.3)	(35.0)	—	—	—	—	34.5
All ranks[b]	34.2	36.6	39.0	45.1	51.2	56.0	56.7	60.0	48.5

Note: Where no salary data are shown, sample is too small to provide a meaningful figure; data in parentheses are from relatively small samples, as well, and should be viewed with caution. a Base annual salary as of March 1, 1990, excluding summer teaching and other supplemental earnings; salaries of the approximately 60% of academic chemists who have nine- or 10-month contracts are adjusted to a 12-month basis. b Includes unranked faculty and others not listed separately. **Source:** ACS survey

Women chemists' salaries typically are 10 to 20% lower than their male colleagues'

Mean salary ($ thousands)[a]	B.S.				M.S.				Ph.D.			
	All chemists	Men	Women	Women as % of men	All chemists	Men	Women	Women as % of men	All chemists	Men	Women	Women as % of men
EMPLOYER												
Private industry	$43.6	$46.4	$39.7	86%	$50.5	$52.4	$46.6	89%	$65.1	$66.2	$58.8	89%
Academic	30.4	33.1	25.5	77	36.0	38.7	32.2	83	49.1	50.5	42.6	84
Government	39.2	40.9	37.1	91	43.9	45.1	42.7	95	56.0	57.0	50.8	89
Other	43.3	46.2	36.5	79	48.3	51.0	44.0	86	64.4	66.0	55.5	84

a As of March 1, 1990, to facilitate comparison, women's salaries are adjusted for the difference in average length of experience between them and men. **Source:** ACS survey

In industry, chemists tend to earn highest salaries in management and marketing jobs

Median salary ($ thousands)[a]		Years since B.S. degree										
		0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
CHEMISTS EMPLOYED FULL TIME IN INDUSTRY												
Sex												
Men	B.S.	$ 27.3	$ 29.4	$ 35.0	$ 41.5	$ 45.7	$ 50.0	$ 54.6	$ 56.3	$ 57.0	$ 60.0	$ 42.1
	M.S.	—	33.5	36.8	43.5	48.8	53.0	56.0	60.0	61.2	62.0	49.8
	Ph.D.	—	—	47.0	52.0	59.2	65.4	72.0	73.0	76.0	75.0	60.9
Women	B.S.	26.5	29.0	33.0	37.5	41.3	44.9	41.6	43.8	44.3	(53.0)	34.0
	M.S.	—	33.0	35.6	43.0	46.0	48.0	46.3	45.0	51.0	(50.0)	41.0
	Ph.D.	—	—	46.5	50.3	58.0	60.0	60.0	60.0	62.0	(69.6)	51.5
Work function												
General management	B.S.	—	34.5	36.0	45.0	52.8	63.5	66.5	71.0	64.0	80.0	51.0
	M.S.	—	—	39.1	45.6	53.2	70.0	60.9	72.0	(74.6)	85.0	58.2
	Ph.D.	—	—	(47.5)	58.7	65.0	78.0	85.5	89.1	88.9	100.0	78.8
R&D management	B.S.	—	(34.5)	42.0	48.5	58.0	62.1	69.0	67.0	70.0	65.0	59.2
	M.S.	—	—	35.2	52.0	55.5	64.2	66.0	68.5	75.0	64.0	60.0
	Ph.D.	—	—	50.0	59.0	66.7	74.0	80.0	86.2	91.0	90.0	75.0
Basic research	B.S.	28.0	29.0	32.5	37.5	42.5	(46.4)	(46.9)	(53.0)	—	—	32.5
	M.S.	—	34.0	36.0	40.0	45.4	51.5	52.0	(53.0)	(67.7)	—	42.0
	Ph.D	—	—	47.8	52.0	58.0	62.6	70.0	70.0	78.0	78.0	55.0
Applied research[b]	B.S.	26.3	29.9	34.8	39.6	43.2	48.0	50.2	52.0	55.2	52.0	37.7
	M.S.	—	33.5	36.5	42.4	47.5	49.1	52.7	57.2	55.0	60.1	45.0
	Ph.D.	—	—	46.5	50.1	56.0	60.1	65.0	65.4	67.8	67.0	55.0
Production[c]	B.S.	27.3	27.6	32.4	38.2	41.0	45.0	48.3	49.7	48.0	43.1	36.5
	M.S.	—	32.0	34.8	42.0	42.5	48.0	51.1	51.9	46.5	(45.0)	42.5
	Ph.D.	—	—	44.8	48.1	55.0	59.5	60.0	(70.0)	57.5	(62.4)	55.0
Marketing[d]	B.S.	(29.1)	31.0	37.8	44.0	49.9	59.0	54.8	54.5	56.1	60.0	45.0
	M.S.	—	—	38.5	46.0	54.5	56.1	57.0	58.2	55.5	60.0	52.0
	Ph.D.	—	—	(44.0)	50.6	60.0	64.3	69.5	67.0	66.4	(70.0)	61.0
Work specialty												
Agricultural and food chemistry	B.S.	—	26.2	33.3	35.9	44.5	47.8	(48.0)	(50.8)	(55.2)	—	35.9
	M.S.	—	—	(36.2)	43.5	45.9	53.6	(70.0)	(60.0)	(62.0)	(59.0)	48.0
	Ph.D.	—	—	45.7	49.0	58.0	61.4	69.1	74.5	84.1	(83.5)	59.0
Analytical chemistry	B.S.	26.1	28.6	33.0	38.8	42.7	47.3	48.4	50.8	50.0	52.0	37.5
	M.S.	—	30.4	35.0	42.3	46.0	50.0	51.0	54.0	56.2	60.1	44.1
	Ph.D.	—	—	46.0	51.2	58.0	62.0	65.4	67.1	68.0	67.2	56.0
Biochemistry	B.S.	—	30.0	31.0	(39.6)	(46.1)	—	—	—	—	—	35.1
	M.S.	—	—	(35.0)	38.5	(42.5)	(52.0)	(49.0)	—	—	—	42.0
	Ph.D.	—	—	(47.0)	51.5	57.0	60.5	68.9	(72.0)	82.9	(79.5)	58.2
Biotechnology	B.S.	—	29.2	33.0	(44.0)	(50.0)	—	—	—	—	—	34.9
	M.S.	—	—	38.0	43.3	44.0	(48.8)	—	—	—	—	44.0
	Ph.D.	—	—	46.2	55.0	59.0	70.2	73.0	83.0	(79.6)	—	60.0
Environmental chemistry	B.S.	25.0	28.0	34.0	42.4	46.5	48.2	49.5	56.5	60.0	—	37.9
	M.S.	—	(32.6)	38.0	43.5	48.0	50.0	(54.8)	(53.0)	(59.8)	(60.0)	45.0
	Ph.D.	—	—	43.1	48.5	57.0	63.0	67.0	75.0	64.8	(72.0)	61.7
Inorganic chemistry	B.S.	(26.0)	(28.0)	35.0	36.2	(41.2)	(52.0)	(46.0)	(54.6)	(61.0)	(53.5)	40.8
	M.S.	—	—	—	(48.8)	(51.2)	(50.0)	(56.3)	(60.4)	—	(55.0)	(50.9)
	Ph.D.	—	—	46.0	52.0	57.7	60.0	70.0	69.0	78.0	72.7	57.1
Materials science	B.S.	—	32.0	36.0	43.0	43.0	45.6	54.8	58.4	56.0	(67.0)	42.0
	M.S.	—	—	40.5	45.2	50.6	58.0	51.2	62.0	67.2	(51.0)	50.6
	Ph.D.	—	—	47.3	52.0	60.0	67.5	71.0	72.5	72.2	73.0	62.0
Medicinal and pharmaceutical chemistry	B.S.	(29.2)	30.2	34.7	39.7	45.0	60.5	55.0	(54.0)	(62.5)	(65.8)	37.3
	M.S.	—	(33.7)	36.0	42.0	47.8	50.5	55.6	(50.8)	(57.5)	—	43.0
	Ph.D.	—	—	48.0	54.0	60.5	70.0	74.0	78.0	86.0	94.0	60.0
Organic chemistry	B.S.	(26.8)	29.4	35.0	40.1	45.0	50.7	54.3	55.0	60.0	63.0	40.0
	M.S.	—	(34.0)	36.1	40.2	47.0	52.0	53.2	57.2	54.0	63.0	46.0
	Ph.D.	—	—	45.7	51.0	57.0	65.0	70.0	72.5	73.5	75.4	59.0
Physical chemistry	B.S.	—	(32.6)	37.2	(40.0)	(47.0)	(47.4)	(52.0)	—	(60.0)	—	43.6
	M.S.	—	—	(37.5)	(44.8)	(50.0)	(59.0)	(69.2)	(68.5)	—	—	51.3
	Ph.D.	—	—	47.5	52.0	61.0	64.0	72.7	71.8	71.2	66.2	60.2
Polymer chemistry	B.S.	28.6	30.0	35.0	42.5	48.0	57.0	57.2	53.4	59.6	60.0	43.0
	M.S.	—	(34.0)	37.0	47.0	50.8	55.0	59.4	59.9	61.0	60.0	50.0
	Ph.D.	—	—	47.8	51.4	58.4	66.0	71.3	72.0	76.0	71.0	61.7

Note: Where no salary data are shown, sample is too small to provide a meaningful figure; data in parentheses are from relatively small samples as well, and should be viewed with caution. a As of March 1, 1990. b Includes development and design. c Includes quality control. d Includes purchasing, technical service, and economic evaluation.
Source: ACS survey

Unemployment has hovered at about 1% for chemists since the mid-1980s

Employment status[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
Employed full time	95.2%	95.3%	95.4%	95.4%	94.8%	95.2%	93.7%	93.5%	94.9%	95.6%	95.9%
Employed part time	1.4	1.5	1.6	1.5	1.5	1.5	1.7	1.7	1.4	1.1	1.0
Postdoctoral or fellowship	2.2	2.2	2.0	2.0	2.0	1.9	2.9	2.6	2.2	2.2	2.2
Unemployed	1.1	1.0	1.0	1.1	1.7	1.4	1.7	2.2	1.5	1.1	0.9

[a] As of March 1, 1990; excludes chemists who are not employed but not seeking employment. **Source:** ACS survey

women in industry whose highest degree is a B.S. that they received 30 to 39 years ago is 22% less than that for men of similar training and experience; the median in industry for women with a Ph.D. who obtained their B.S. 30 to 39 years ago is 18% lower than that for similar men.

As usual, chemists working in industry generally report higher salaries this year than those with jobs in government agencies or in academic institutions. And the highest salaries are paid to industrial chemists working for petroleum and gas firms.

Not surprisingly, salaries tend to be highest for industrial chemists with managerial duties. Thus, at the higher levels of experience, median salaries for Ph.D.s involved with management of research and development tend to be about a third greater than for those actually doing applied research and development themselves.

Salaries seem to differ little from one section of the U.S. to another. The median salary of Ph.D. chemists in industry ranges from a high of $61,000 in the Pacific and Middle Atlantic regions to a low of $55,700 in the Rocky Mountain region. What regional differences do exist largely reflect differences in the types of industry the employee works for and the fact that certain industries tend to concentrate in certain geographical areas. Within individual industries, salaries are relatively similar across regions.

Base salaries are not the only earnings received by chemists, of course. About half of industrial chemists report that they were eligible for a bonus last year, and of these 90% actually received a bonus. As would be expected, the biggest bonuses went to chemists in management positions; the median bonus for chemists in general management was $8500, for chemists in R&D management $8000. For employees working in marketing, the median bonus was $4800. At the other end of the scale, chemists doing research report a median bonus of $2500 and for those with production duties the median was $2000.

Unemployment lowest in government and academia

	% of chemists in category	% unemployed[a]
MOST RECENT EMPLOYER		
Industry	58%	1.2%
Academia	25	0.6
Government	9	0.4
Other	9	2.1
MOST RECENT WORK FUNCTION		
R&D	46%	1.1%
Teaching	12	0.4
R&D management	11	1.3
Production[b]	7	1.5
General management	6	1.3
Marketing[c]	4	1.5
Other	14	1.3
MOST RECENT WORK SPECIALTY		
Analytical chemistry	21%	1.0%
Organic chemistry	14	0.8
Polymer chemistry	11	1.0
Environmental chemistry	9	1.3
Physical chemistry	7	0.9
Biochemistry	7	1.1
Medicinal chemistry[d]	6	1.5
General chemistry	6	0.7
Materials science	5	1.0
Inorganic chemistry	5	0.7
Agricultural chemistry[e]	3	0.9
Biotechnology	2	1.8
Clinical chemistry	1	2.2
Other chemistry	3	1.9

[a] As of March 1, 1990, excludes chemists who are not employed but not seeking employment. [b] Includes quality control. [c] Includes sales, purchasing, technical service, and economic evaluation. [d] Includes pharmaceutical chemistry. [e] Includes food chemistry. **Source:** ACS survey

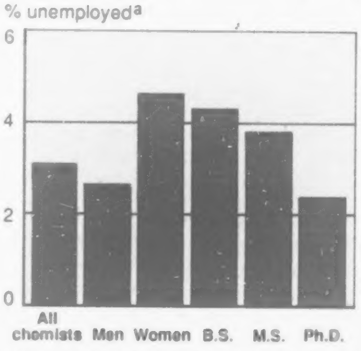
The low 1.1% rate of unemployment among chemists as of last March 1 does not completely reflect their recent job status. In addition, 3.1% of respondents to the ACS survey report that sometime during 1989 they were without work. Women, 4.7% of whom were unemployed at one time or other during the year, were nearly twice as likely as men to have been jobless, and chemists with just a B.S. degree nearly twice as likely as Ph.D. chemists.

Jobless chemists generally found work in less than four months

Months unemployed anytime during 1989	Less than 1	1 to 3	4 to 6	7 to 12
All chemists	10%	46%	25%	19%
Men	9	48	26	17
Women	12	59	20	9
Highest degree				
B.S.	12	60	19	9
M.S.	12	45	27	15
Ph.D.	6	46	27	21
Minority	7	48	31	14
Nonminority	10	51	24	15

Note: Excludes chemists not in the labor force March 1, 1990. **Source:** ACS survey

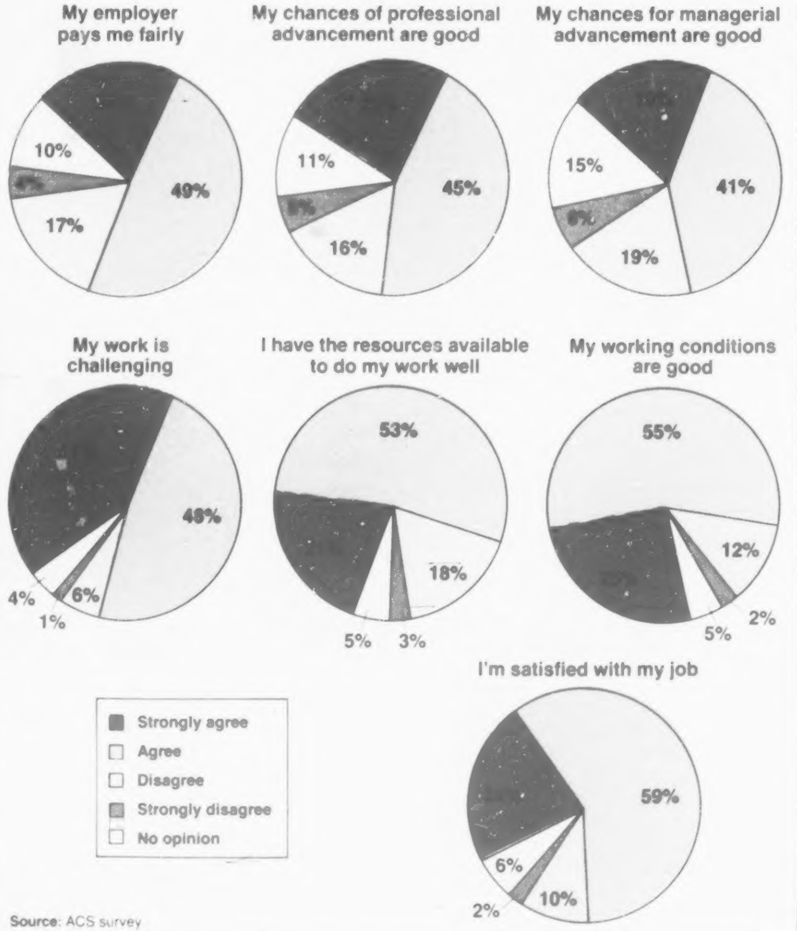
About 3% of chemists were jobless sometime last year



[a] Excludes chemists who were not employed but not seeking employment. **Source:** ACS survey

Most jobless chemists were successful in obtaining new positions

Most chemists say they are satisfied with their work



Source: ACS survey

relatively quickly, however; 56% in three months or less. Only 19% were out of work for more than six months. Although they were more often unemployed, women tended to find jobs more quickly than men, and B.S. chemists more quickly than those with a Ph.D. Of the unemployed chemists looking for work last March, about 40% had been jobless for only three months or less.

The broadly favorable picture painted by the ACS survey may tend to mask the economic plight of at least a handful of chemists. As of March 1, about 0.2% were without work and had been unsuccessfully searching for it for more than a year—a small but by no means negligible group. And about 0.3% were working part-time only because they were unable to obtain a suitable full-time position. Also on the downside, while half of nonacademic chemists whose highest degree is a B.S. earn $39,000 or more a year, 10% (most of them relatively young) have a salary of $26,000 or less. In fact, 10% of nonacademic chemists who received their B.S. less than five years ago earn $22,000 or less and a few below $20,000 annually. About 4% of chemists have a strong belief that they are not paid fairly compared with fellow employees who have similar duties and responsibilities.

Nevertheless, chemists generally seem to be satisfied with their working conditions and their opportunities for promotion. Women, by and large, are less pleased than men regarding prospects for advancement; 64% of women (compared with 69% of men) see their chances for professional advancement to be as good as their fellow workers, and only 54% (compared with 61% for men) think they have as good a chance for managerial advancement. A fourth of women chemists, compared with a fifth of men chemists, do not think they are paid fairly.

Working for a college or university seems to enhance job satisfaction; 87% of academic chemists find their work satisfying most of the time, compared with 81% of chemists in industry and 80% in government. Among academic chemists, too, 95% consider their work challenging (including 56% who strongly think so) versus 88% of industrial and 86% of government chemists. Government chemists are least likely to be satisfied with what they earn; 31% do not think they are paid fairly, compared with the 24% of academic chemists and 19% of industrial chemists who are of this opinion.

Results of this year's ACS survey of the economic status of its members, sponsored by the Joint Board-Council Committee on Economic Status, are based on responses to questionnaires sent to all members living in the U.S. who are not more than 70 years of age and who have neither retired nor student status. Previous similar surveys since 1985 were derived from a smaller random sample of such members. The data reported here are based on more than 39,000 reponses, compared with 10,000 to 15,000 responses of other recent surveys. Consequently, they provide much more detailed salary and job information for a broader array of chemists than has been available from surveys of the past four years.

Considerably more comprehensive information on the survey results is available in "Salaries 1990," which can be purchased from the ACS Distribution Office, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. The price of a copy of the report this year is $170. In addition, by year's end ACS will publish a report entitled "Women Chemists 1990" based on data from the survey and priced, $39.95. Questions or comments concerning the survey can be directed to Joan Burrelli at ACS headquarters in Washington; her phone number is (202) 872-4433. ☐

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NEWS

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AIDS Conference

Vaccine work highlights research progress
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Volume 68, Number 29
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CHEMICAL & ENGINEERING NEWS

JULY 16, 1990

News of the Week

- **The recent fire and explosion at Arco Chemical's Channelview, Tex., petrochemical complex that killed 17 workers have spotlighted the continuing concerns about safety of petrochemical plant operations.** Page 4
- **GE scientists have prepared diamonds of nearly pure carbon-12 that have much higher heat conductivity than natural diamonds but that are still electrical insulators.** Page 5
- **London meeting to amend the Montreal protocol left dangling the future of hydrochlorofluorocarbons, under development as substitutes for chlorofluorocarbons.** Page 5
- **Patients don't own cells or tissue removed during medical procedures, and they can't share in profits from commercial use of them, California Supreme Court has ruled.** Page 6

Cover: Photo by C&EN's Rudy M. Baum

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Business

Random testing of employees for drug and alcohol abuse is being carried out by an increasing number of chemically related companies. **Page 17**

Government

The continuing decline in new research grants from NIH has research workers scrambling to find some solutions. **Page 20**

The House has cut back on NSF and NASA budget requests in fiscal 1991 appropriations bill that now goes to the Senate. **Page 22**

Science/Technology

Biotechnology techniques, based on principles of protein chemistry, are being exploited to produce new advanced materials. **Page 26**

Books

"Brainstorming: The Science and Politics of Opiate Research" is a personal account by scientist Solomon Snyder of the process and politics that led to the discovery of opiate receptors. **Page 34**

News Focus

Advances in research on AIDS vaccine, which scientists now think could be available by the end of the 1990s, highlighted 6th International Conference on AIDS. Page 7

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LETTERS

Shakhashiri praised

As faculty members of the Carleton College chemistry department we have greatly admired the achievements of Bassam Z. Shakhashiri. As Assistant Director for Science and Engineering Education at the National Science Foundation, he has generated excellent programs based on sound philosophy. We need leaders with the vision, energy, and charisma of Shakhashiri to improve the sad state of science education in this country.

The recent, abrupt dismissal of Shakhashiri from his outstanding work (C&EN, June 4, page 5) is a morale-crushing blow to those of us who appreciated his creative and dedicated style. What a grim message Erich Bloch has sent to the science education community: Don't be so good at your job that you become popular with Congress and highly visible to those who need inspiration. We are outraged at this action.

Lynn A. Buffington
Charles H. Carlin
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Jerry R. Mohrig
Richard W. Ramette
Carleton College
Northfield, Minn.

Shortage of chemists

In recent letters and articles in C&EN, concern has been expressed about the shortage of Ph.D. chemists. This is not much of a surprise to me as a native of Germany who received a Ph.D. in chemistry at the University of Hamburg. I would say that this shortage is caused by three factors.

First, the great majority of American students are finishing their chemical education with the award of a bachelor's or master's degree. Second, there is a lack of true willingness to spend six years to get to the top, which a Ph.D. degree symbolizes. Third, there is a lack of genuine interest in chemistry, which unfortunately has a poor public image—particularly in America, the greatest industrial country on Earth. This image is of course exaggerated and distorted. The general public tends to remember mostly the bad things, such as air and water pollution, Chernobyl and Bhopal, oil spills from tankers, Hiroshima, and Three Mile Island.

Now let me add some details. The bachelor's and master's degrees do not exist in most European countries. Hence, almost every student who wants to become a professional chemist must go all the way that leads to the doctorate, which is based on a doctoral dissertation that usually takes at least two years of laboratory work. Parents of most European middle-class families, with a maximum of three children, can well afford and are very proud to send their children to a university, assuming of course that they want it and have the stuff for it. There is no federal support for graduate education, no living allowances, no fellowships and stipends. Nobody expects financial support from the government. However, it should be noted that all these benefits will be available after graduation.

In Europe there is no shortage of Ph.D. chemists, never was, and never will be. The European Ph.D. degree has a special lustre and prestige. It is a very special privilege to possess, all of which it does not have in America. There is, of course, a great demand for chemists with a B.S. and M.S., although these still have only a restrictive choice in their search for a position. All universities, colleges, and research institutes are explicitly looking for Ph.D. chemists, and most key positions in the chemical and pharmaceutical industry are mostly reserved for chemists with a Ph.D. degree.

Indeed, one wonders why in the richest country in the world (which has become the research center of the world), only 30% of all chemists have a Ph.D. degree.

Carl Tiedcke
ACS 50-year member emeritus
Santa Barbara, Calif.

Who governs our image?

Raymond B. Seymour's lament (C&EN, April 2, page 35) concerning the image of our profession and the lack of awareness of ACS by state governors was right on. However, in addition to Rudy Perpich of Minnesota, at least one other governor knows about us. He is James Martin of North Carolina, who has won the ACS Parsons Award and who, as governor, presented an Outstanding Local Section Award to the Central North Carolina Section in Greensboro a few years ago. The event was a great success and drew two congressmen as well.

Are there other governors to add to this short list, and if not, is it their fault or ours?

Robert B. Fox
Naval Research Laboratory
Washington, D.C.

Corporate Testing for Drug, Alcohol Abuse on the Increase

C&EN survey shows that more major chemical companies are performing random testing, especially in safety-sensitive jobs

Marc S. Reisch,
C&EN Northeast News Bureau

Random testing of employees for drug and alcohol abuse is on the rise in the chemical industry. Despite the crazy quilt pattern of state regulations that make nationwide drug policies difficult to enforce, federal regulation through the Department of Transportation (for testing truckers of interstate hazardous material shipments) and the Federal Aviation Administration (for testing airplane pilots) has helped encourage companies in their decision to test chemical industry workers—especially those in safety-sensitive jobs.

In a recent survey of 19 chemically related companies, C&EN found that 14 have policies on random testing. One company, Phillips Petroleum, just instituted a policy subjecting all U.S. employees, including executives, to "unannounced, periodic testing . . . except where prohibited by state law." It is the most wide-ranging of any company policy among those surveyed. Phillips did not previously test all employees.

C&EN staff photo

Technician uses automated analyzer to test urine sample for presence of illegal drugs

Thirteen other companies in the survey test employees on a random basis for substance abuse in a variety of instances. Five companies test workers in critical safety-related jobs as site managers see fit. Two test all employees in safety-related jobs as a matter of corporatewide policy. At BASF, all workers at two sites are subject to drug testing. Five other companies, however, subject employees to testing only to satisfy federal regulations.

When C&EN conducted a similar survey in 1987 of the same 19 companies, all required preemployment testing of prospective employees, but only two companies had any policy regarding random tests of employees (C&EN, Aug. 3, 1987, page 7). Where random tests were performed, they were limited to specific sites or divisions.

Regular, periodic examinations are still the policy at Amoco as they were in the 1987 survey. Amoco's testing policy is incorporated into the annual health checkups it requires of plant employees, including first-line supervisors and lab workers who handle chemicals. Testing results are not available to supervisors except if employees allow the medical department to release those results or if the exam involves workmen's compensation resulting from an injury, says John H. Mitchell, corporate medical director for the company.

In cases involving accidents, however, for-cause testing is nearly universal. But Du Pont, General Electric, and Hoechst Celanese do not enforce testing at all of their plants for drug or alcohol abuse when an employee's performance seriously deteriorates or when employee involvement in a plant accident leads to a suspicion of drug abuse. Testing for abuse is at the option of site managers, according to corporate guidelines.

Phillips Petroleum, in instituting its mandatory drug testing policy, notes the force of the federal government's persuasion in its policy statement to employees. "The federal government directly and through its regulatory agencies has directed employers to take specific steps to deal with the problem of substance abuse," Phillips says. The policy adds that "as a federal contractor, the company is obligated under the Drug Free Workplace Act of 1988 to have a clear policy on drugs and alcohol, to communicate such policy to employees, and to undertake efforts to achieve a drug-free workforce and workplace."

Phillips denies any clear connection between its newly stated substance abuse policy and the Oct. 23, 1989, explosion at its Pasadena, Tex., polyethylene complex in which 19 people were killed. The Occupational Safety & Health Administration ruled in April that the accident was due to "failures in the management of safety systems" (C&EN, April 30, page 6). But the concerns outlined in its employee substance abuse policy must play a role now in the firm's management of safety systems: "The safety of our employees, protection of our environment, quality of our products and services, and the financial performance of our company can be directly and adversely affected by the use or abuse of unauthorized, prohibited, illegal or controlled substances including alcohol, drugs, and other chemicals."

Phillips' policy regarding substance abuse goes beyond its own employees. It also includes "all contractors, visitors, vendors, consultants, or other individuals working on company property or company assignments." While Phillips' policy admits it cannot force compliance by outsiders, it notes that those "found or suspected to be in violation" will be "denied access to the job site or work assignment."

Most companies do not see an immediate need for so inclusive a substance abuse testing program as Phillips has in place. Hercules' corporate medical director, Robert T. Beattis, says that Hercules has not found a high incidence of abuse when it has tested its workers. When workers have tested positive, rehabilitation has been high.

ICI Americas' Mark Dobbins, director of training and industrial relations, sees no internal evidence that the company's for-cause-only testing policy is not serving the company's needs. Most important, he believes, is that the company be clear in its policy that employees must be fit for work, and that substance abuse is not acceptable. If any employees do have a substance abuse problem, the company wants to make every effort to help them rehabilitate. Like all the other companies in the survey, ICI pays a share of rehabilitation benefits through the insurance package in which an employee is enrolled.

Like ICI's Dobbins, Jeff Gleason, manager of employee assistance at Olin, says the testing is not meant to be punitive. "The focus is not on punishment, but remediation." Olin tests employees in designated safety-sensitive jobs where it is allowed according to state law and by agreement with the employees' union. That has been a policy since 1987, he says. If the employee objects, he or she is given the opportunity to work in another less sensitive job.

Many chemical firms screen employees for drug abuse

Company	Preemployment	Existing employees			GC/MS confirmation[a]	Employee assistance programs
		For cause	Regular	Random		
American Cyanamid	●	●		●[b]	●	●
Amoco	●	●	●[c]	●[b]	●	●
Arco Chemical	●	●			●	●
BASF	●	●		●[d]	●	●
Borden	●	●		●[b]	●	●
Ciba-Geigy	●	●			●	●
Dow Chemical	●	●		●[c]	●	●
Du Pont	●	●[d]		●[e]	●	●
Eastman Chemical	●	●			●	●
General Electric	●	●[d]		●[e]	●	●
Hercules	●	●		●[e]	●	●
Hoechst Celanese	●	●[d]			●	●
ICI Americas	●	●			●	●
Mobay	●	●		●[b]	●	●
Monsanto	●	●		●[c]	●	●
Olin	●	●		●[c]	●	●
Phillips Petroleum	●	●		●	●	●
Shell Oil	●	●		●[b]	●	●
Union Carbide	●	●		●[e]	●	●

a Gas chromatography and mass spectrometry. b Transportation workers subject to federal testing requirements. c In safety-sensitive jobs. d Not at all sites, but instituted by site managers according to company policy manual. e Not at all sites but instituted by site managers for certain critical safety-related jobs.

Amoco's Mitchell says that the company's substance abuse testing program is part of an overall wellness program, which ensures the productivity of an employee as well as his or her overall safety and health.

Some employees, notes Bill Kovack, Union Carbide's corporate director of employee relations, welcome substance abuse testing, because it takes their personal safety into consideration. Other employees are not so receptive to such policies. The attitude of labor unions with which the company deals is that they neither disagree nor agree with testing policies.

John H. Kirkman, BASF's corporate director of industrial relations, says that at the sites where BASF tests employees, the unions are concerned both about the accuracy of tests and the chain of custody for samples. As a result, the company, like all the others in the survey, uses only labs approved by the government through the National Institute on Drug Abuse. Contractors are expected to "live by our rules," says Kirkman, which is a "a widely held practice."

According to Elmer Greene, medical director for Eastman Chemical, for-cause testing is a condition of employment at the company, and the objective is a safe working environment. The company, he says, shows a lot of compassion when an employee has a substance abuse problem, and the employee assistance program offered employees generally gets good results in helping rehabilitate an employee. Most for-cause testing turns up positive results for alcohol, he says, while most preemployment tests come back positive for marijuana use.

American Cyanamid's corporate medical director, Michael Utidjian, says management should never be allowed to demand that an employee be tested for substance abuse. The decision, he says firmly, is a medical one. Endocrine disorders and psychiatric illnesses may be the cause for all types of unusual behavior, and the decision to test an employee for substance abuse should ultimately be up to a qualified doctor. □

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Outlook remains strong for 75-year-old Fischer-Tropsch technology Page 27

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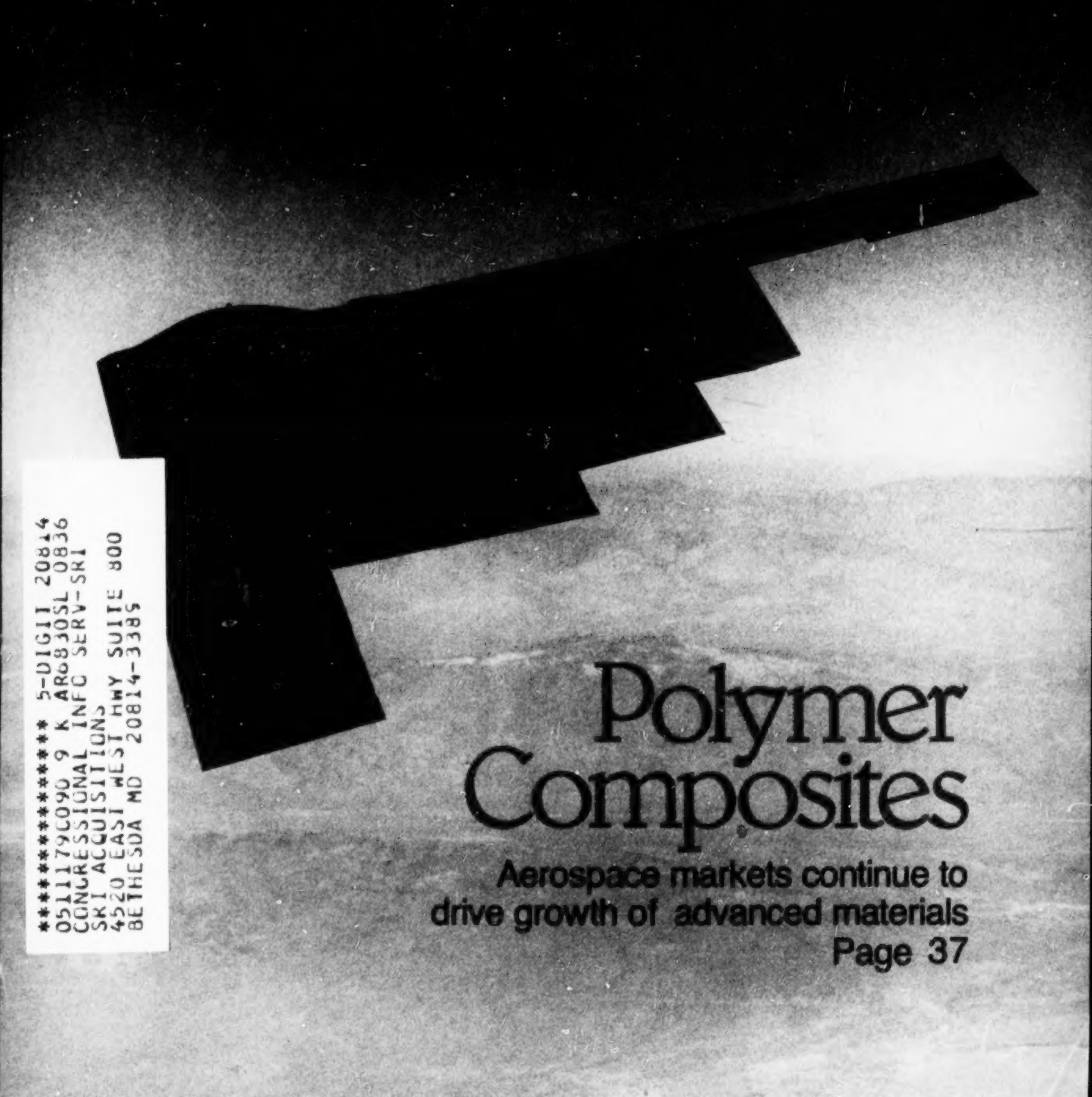
CHEMICAL & ENGINEERING NEWS



Polymer Composites

Aerospace markets continue to drive growth of advanced materials Page 37

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CHEMICAL & ENGINEERING NEWS

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News of the Week

- **Science-related federal agencies could suffer catastrophic cuts if Congress allows budget-deficit dictated, Gramm-Rudman-Hollings cuts in federal spending to take place.** Page 4
- **At International Chemistry Olympiad in Paris, U.S. team made its best showing ever, won one gold and three silver medals to place fourth.** Page 4
- **National Research Council report criticizes U.S. programs for storing high-level radioactive waste.** Page 5
- **Next week NIH's DNA Advisory Committee is expected to approve first clinical trials of human gene therapy.** Page 5
- **Voluntary retirement is offered to hundreds of employees by Schering-Plough and Hoechst Celanese.** Page 6
- **ICI is reorganizing its specialty chemicals into one cohesive unit, ICI Specialties, in a move to accelerate their growth.** Page 6

Cover: Air Force's B-2 stealth bomber.
Photo courtesy of Northrop Corp.

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Business

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House-Senate conference committee has begun work on clean air legislation, faces some time-consuming debate; use of U.S. science information resources lacks federal leadership; progress, plans in cleaning up hazardous waste are assessed by EPA. **Page 17**

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Council faces two petitions, other business at next month's meeting in Washington, D.C. **Page 67**

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LETTERS

CHEMICAL SAFETY

Mixtures of sulfuric acid and hydrogen peroxide

Relative to the letter by Robert G. Bergman and his associates on the explosions of mixtures of sulfuric acid and hydrogen peroxide (C&EN, April 23, page 2), I would like to report the following thoughts and observations.

The Berkeley explosion reminded me of an explosion the results of which I observed *in* the late 1950s. At that time we had found that a mixture of ammonium hydroxide and hydrogen peroxide was extremely effective in cleaning silicon surfaces. A junior chemist in the transistor pilot line laboratory mixed a batch of this reagent in a 5-gal glass container and stoppered it in violation of my instructions to mix only small batches and never have it in a closed container. The reagent exploded, driving shards of glass into a wall at the opposite side of the laboratory (about 60 feet away). Fortunately, no one was in the laboratory at the time of the explosion.

One of the methods of synthesizing peroxydisulfuric acid is to oxidize sulfuric acid with hydrogen peroxide. The hydrolysis product of peroxydisulfuric acid is the notorious Caro's acid. It might appear that the ammonium hydroxide and sulfuric acid reactions are very different. Consider, however,

$$(1)\quad NH_3(aq) + 1.5\,H_2O_2(aq) \rightarrow 0.5\,N_2(g) + 3\,H_2O(l)$$

$\Delta G = -484$ kilojoules per 1.5 moles H_2O_2

and

$$(2)\quad 3\,H_2SO_4(l) + 1.5\,H_2O_2(aq) \rightarrow 1.5\,H_2S_2O_8(aq) + 3\,H_2O(l)$$

$\Delta G = -112$ kilojoules per 1.5 moles H_2O_2

followed by

$$(3)\quad 1.5\,H_2S_2O_8 + 1.5\,H_2O(l) \rightarrow 3\,H_2SO_4(l) + 1.5\,O_2(g)$$

$\Delta G = -42$ kilojoules per 1.5 moles H_2O_2

While there is a significant difference between −484 and −154, an exoergonicity of 154 kilojoules is not trivial.

Sheldon L. Matlow
Chairman of the Board/CEO
Nace Technology Inc.
San Jose, Calif.

Financial rewards

That many of us in the chemistry profession are quite concerned with the decline in bright students entering the field is certainly an understatement. I have, however, been waiting among all the letters on this topic for an additional important point to be brought out that I believe has a tremendous impact on the whole issue. This issue is certainly multifaceted, but to me, it is self-evident that you get what you pay for, and industry at current does not pay high salaries for good chemists. The really top compensation goes only to the managers.

I do not wish to take anything away from managers, but I assume that most of us who entered chemistry did so because we love doing just that—chemistry. If we had wanted to be managers, we should have gone into business administration, a path with considerably less investment in time and money to reach the final goal. I, incidently, do not agree with the assessment of Joel T. Mague (C&EN, April 16, page 55) that those of us expecting extra compensation for extra effort are lazy and greedy. Rather, I feel it is a sad state of affairs when making a choice to remain close to chemistry means finding that it has all but eliminated chances for top financial reward (and also recognition) in an industrial research setting.

But yet, if we choose to distance ourselves from chemistry, the compensation package begins now to be quite lucrative. It is, I believe, hard for most of us to get excited about doing good research only to see someone else reap the rewards for our work. It is my opinion that until such a problem is addressed and rectified by actually paying chemists to be good at doing chemistry, instead of doing management functions for which chemists seem to be poorly trained in general, that we will have trouble attracting the bright stars we all want to see.

I doubt, however, that most managers can be expected to voluntarily pay their good people more to stay at the bench than they themselves are compensated. Normal people would be expected to have problems with such a state of affairs. Such a change will have to be

Chemical Firms Wait Out Canada's Constitutional Crisis Over Quebec

Uncertainty of relationship of Quebec, key part of chemical industry, with rest of nation presents tough questions for Canadian, U.S. companies

For the Canadian chemical industry, and for U.S. chemical companies doing business in Canada, it is "business as usual" while federal and provincial politicians figure out where to steer the country now that the Meech Lake constitutional accord has been scrapped.

The Meech Lake accord, named after the lake near Ottawa where the agreement was hammered out in April 1987, would have granted the French-speaking province of Quebec "distinct society" status. To become effective, Canada's 10 provinces had to ratify the accord—unanimously—by the June 23 deadline. When Newfoundland and Manitoba failed to ratify the agreement, Meech Lake died and plunged Canada into a constitutional crisis.

The big question now, of course, is what kind of relationship there will be between Quebec and the rest of Canada. The possibilities range from remaining in the Canadian federation under the status quo, which is highly unlikely, to outright secession. In between are several other options, including "sovereignty association," an ill-defined term that no doubt would encompass some kind of loose economic, if not political, association.

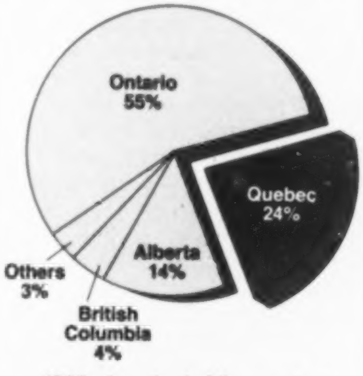
The ball is in Quebec's court, where separatist sentiment never has been higher. However, Quebec's premier, Robert Bourassa, has set up a nonpartisan commission to study the possibilities and define Quebec's new relationship with Canada by next March. The commission's recommendations could be followed by a referendum in Quebec.

Meanwhile, Canadian and U.S. chemical leaders are groping for answers to several important questions. What impact will the political uncertainty have on both domestic and foreign chemical investment—in Quebec and the rest of Canada? What will happen to interprovincial chemical trade between Quebec and the other Canadian provinces? What will happen to the Canada-U.S. free trade agreement, still only about 18 months old? How will any possible impact on the Canadian dollar trickle down into other nooks and crannies of the Canadian economy?

Until something specific happens in the political arena, business leaders can only speculate about the answers. And there's very little that Canadian chemical companies can do except "business as usual."

W. Norman Kissick, chairman and chief executive officer of Union Carbide Canada, says that business executives have very little to go on as far as the near-term future is concerned. Carbide Canada, 75% owned by Union Carbide Corp. (Danbury, Conn.), has chemical operations in Quebec as well as in other Canadian provinces. Until Quebec comes up with an approach that is best from its perspective, adds Kissick, chemical companies will just have to ride out the uncertainty.

24% of Canada's chemical shipments begin in Quebec



1989 chemical shipments = \$19.9 billion (U.S.)[a]

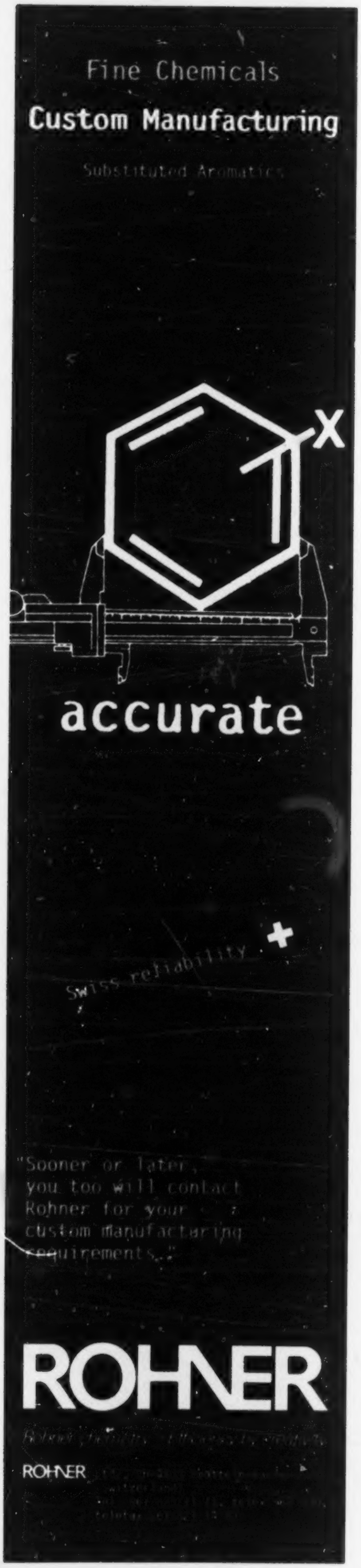
[a] At current exchange rates, \$1.00 U.S. = \$1.16 Canadian. Source: Statistics Canada

Andre Lapalme, president of Pétromont, agrees. He says the death of the Meech Lake accord has had no direct impact on the chemical industry "that you can measure." He is more concerned about the long-term stability of the market. Lapalme points out that, for Pétromont, the market is not just Canada, but the U.S. as well.

Lapalme concedes that, if political instability arising out of the Meech Lake situation continues for an inordinate length of time, there could be reason for concern about chemical investment in Quebec. However, he believes that, compared with the separatist movement in the early 1980s, Quebecers are taking a much more mature approach.

The petrochemical buildup in Alberta and the "chemical valley" of Sarnia, Ontario, notwithstanding, Quebec is a very important part of the Canadian chemical industry. Last year, the province accounted for \$4.7 billion worth of chemical shipments. That's a hefty 24% of the Canadian total.

Pétromont is the cornerstone of Quebec's petrochemical industry. The company, owned jointly by Union Carbide Canada and Ethylec Inc. (a wholly owned subsidiary of the Quebec government agency Le Groupe SGF), produces ethylene, propylene, and other chemicals at its



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petrochemical complex in Varennes, across the St. Lawrence River from Montreal. It also has a long-term lease on an old, high-pressure, low-density polyethylene (LDPE) plant that Union Carbide Canada owns and operates for Pétromont at Montreal East.

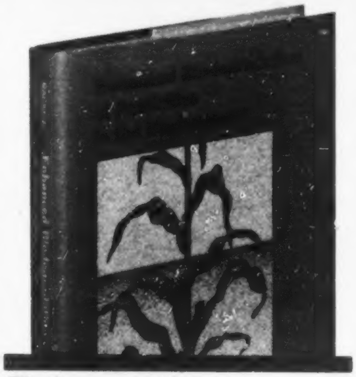
Pétromont, which suffered through some lean years in the early and mid-eighties, now has some ambitious expansion plans in the works. It is acquiring the old LDPE plant at Montreal East from Union Carbide Canada, will gradually phase out LDPE production, then shift to high-density polyethylene (HDPE). HDPE will be produced in a new, 200,000 metric-ton-per-year plant that Pétromont is building at Montreal East. Pétromont will market part of the plant's output in Canada, while Union Carbide will market the remainder in the U.S. and outside North America.

Meanwhile, Pétromont also is adding a sixth cracker to expand ethylene capacity at Varennes from 220,000 metric tons to 265,000 metric tons per year. The ethylene expansion is scheduled to be completed by the time the HDPE unit comes on stream in Montreal East—probably early next year. But for Pétromont and the rest of the petrochemical industry in the Montreal area, much is riding on the completion of the so-called Soligaz pipeline project to carry much-needed natural gas liquids from western Canada to Montreal. Soligaz is a consortium of companies that includes Pétromont.

The original plan of the long-delayed project was to build a pipeline from Sarnia, Ontario, to Montreal to carry natural gas liquids that Pétromont would use as feedstock for its olefins units. Now the consortium is considering an alternate plan. It is studying the possibility of using the existing Cochin pipeline and other lines through the U.S. and constructing a new pipeline from northern New York State to Montreal.

A lot of petrochemical investment has been riding on the outcome of the Soligaz pipeline. Over the long term, a lot now is riding on how the politicians shape the future of Quebec and Canada.

Earl Anderson



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Photosynthetic Reaction Centers

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News of the Week

- **Second-quarter chemical earnings show little pattern, ranging from sizable declines to respectable increases.** Page 6
- **French group develops copper complexes that mimic the double-helical structure of DNA but turn it "inside-out," offering a way to gain more insight into this biological linchpin.** Page 7
- **Chemical industry in China begins to rebound from rough and turbulent times, but is still far from "business as usual."** Page 7
- **Explosion at BASF resins plant in Cincinnati kills one and injures 71.** Page 8
- **Hearing on July 5 blast at Arco plant in Texas includes calls for better management-worker communication, defense of using contract workers.** Page 8

Cover: Argonne National Laboratory's computer-generated diagram of photosynthetic reaction center in *Rhodobacter sphaeroides R-26* embedded in bilayer membrane

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Ethyl has been hurt by imports of ibuprofen from India, hopes that proposed trade legislation will provide a remedy. **Page 13**

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New law, regulations on tap for chemical plant safety; implementation will be joint responsibility of OSHA, EPA. **Page 15**

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Federation of European Chemical Societies celebrates two decades of success in enhancing understanding of chemistry's role in Europe. **Page 19**

Scanning tunneling microscope grabs the sharpest DNA image achieved to date. **Page 20**

Department of Energy agrees to share technology with industry consortia representing specialty metals processing, manufacturing sciences. **Page 20**

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"Forty years of Firsts: The Recollection of a Dow Corning Pioneer" by Earl L. Warrick pays homage to silicone's development and other Dow history. **Page 38**

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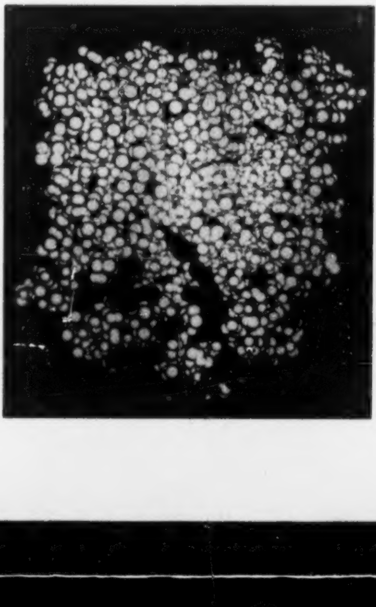
ACS members generally are satisfied with the society's products and services, and supportive of its goals, a survey finds. **Page 42**



Special Report

Chemistry of photosynthesis in purple photosynthetic bacteria begins in membrane-embedded reaction centers, which offer model systems for studying photosynthetic conversion. **Page 22**

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LETTERS

CHEMICAL SAFETY

Tantalum amide preparation

Explosions in two laboratories have prompted us to comment on the preparation of pentakis-dimethylamido tantalum, $Ta(NMe_2)_5$. The original paper by D. C. Bradley and M. Thomas [*Can J. Chem.*, 40, 1355 (1962)] provides a procedure for the synthesis of the compound, which if strictly followed does not give the desired product. The procedure given directs one to add $TaCl_5$ to a slurry of $LiNMe_2$ in pentane.

If one has rigorously purified the $LiNMe_2$ and is careful to exclude moisture, little reaction occurs. One is left with a finely divided mixture of $LiNMe_2$ and $TaCl_5$, which sometimes detonates during routine manipulation.

This can be avoided by preparing the $LiNMe_2$ in situ, being careful to use excess $HNMe_2$. It appears that the reaction progresses initially by reaction of the $TaCl_5$ with the amine [Chisolm, M. H., Huffman, J. C., Tan, L.-S., *Inorg. Chem.*, 20, 1859 (1981)], with the last two or three dimethylamide groups being metathesized onto the tantalum center by the $LiNMe_2$. The reaction has also been found to proceed smoothly to the desired product if a pentane/diethyl ether solvent mixture (50-50) is used.

Robert W. Chestnut
Ian P. Rothwell
Purdue University
Mark Banaszak Holl
Peter T. Wolczanski
Cornell University

Career decisions

Convincing arguments can be made for the desirability of increasing financial support for chemistry students in college and graduate school and for teaching and research equipment, but it seems to me quite unproven that such increased support would increase significantly the number of students who become chemists.

Is it really true that students decide to become chemists after they are in college and not earlier?

Is it really true that students deciding whether or not to become chemists are well informed about the financial rewards of various possible careers in chemistry and are influenced by such information?

Is it really true that significant numbers of capable students are dissuaded from careers in chemistry by large impersonal lecture courses in college general chemistry?

I know of no reason to believe any of these things. The first does not agree with the few studies I have seen and with my own limited observations; the second is highly implausible (where and from whom would students get such information?); and the third seems clearly untestable.

More information about when and why students make particular career decisions seems to me to be a better basis for action than assumptions, no matter how plausible and attractive they may be.

James Moffat
San Antonio

Plastics recyclable

In your product report on aerosols, (C&EN, April 23, page 35), you quoted "another industry source" as stating that "these packages . . . do add to the landfill problem. Unlike metal aerosol cans, the plastics they are made from are not recyclable." According to the article, the inner bottle is made of polyethylene terephthalate, "the same plastic used to make large soda bottles." This plastic has been recyclable for several years now. The outer container, which is probably made of other types of polyethylene, is also recyclable. My neighborhood has been collecting and recycling these plastics for four months now.

I think the nonaerosol packages are great, and it is not a disadvantage that they are made of plastic. Many plastics are recyclable, which is a fact that needs more publicity.

Sharon R. Camp
Mableton, Ga.

Keeping a civil tongue

In Ron Dagani's balanced report (C&EN, April 16, page 28) on the 1st Annual Conference on Cold Fusion in Salt Lake City, I read that "the skeptics were taunted from the podium in much the same way that cold fusion pioneers B. Stanley Pons and Martin Fleischmann were ridiculed last May at an American Physical Society meeting in Baltimore."

I remember well the reports on the Baltimore meeting, and my disgust and

SECOND-QUARTER EARNINGS: Results show little pattern

The immediate future of the economy seems to be a mystery to the experts these days, and equally so to those who follow the fortunes of the chemical industry. Second-quarter financial results for 16 chemical companies reporting so far range from sizable declines to respectable increases, with half of the companies having increases.

Dow Chemical, which set a goal a number of years ago of becoming less dependent on commodity chemicals with their up and down cycles, posted a year-to-year 50% earnings decline. Monsanto, which set the same goal, had an earnings increase of 2%. American Cyanamid, which, because of its big stake in pharmaceuticals, has usually been less cyclical than most chemical firms, registered earnings growth of 11% for the quarter. And specialties manufacturer Lubrizol posted a strong 27% earnings increase.

The biggest disappointment was Dow, whose earnings dropped to $364 million on a 4% sales increase to $4.81 billion. The result was that profit margins at the company fell to a more normal 7.6% in the second quarter this year from a whopping 15.8% in the same period in 1989.

Dow's decline evidently shook Wall Street, which will normally discount a stock for poor earnings prior to release of results. But in this case, Dow's decline—5¾ points, closing at 52⅜—on the New York Stock Exchange came only on the day its results were released.

The problems at Dow came primarily in two business segments—chemicals and performance products, and plastics. For the plastics unit, sales declined 3% to $1.8 billion, but operating income dropped 40% to $279 million. Pricing pressure in thermoplastics in June limited a recovery that had been seen earlier in the quarter, and higher costs and softening demand cut margins in thermosets.

In the chemicals and performance products segment, sales fell 12% to $1.2 billion, but operating income declined 63% to $177 million, partly as a result of chlor-alkali plant outages in Brazil and Canada.

Adding to the earnings decline were increases in nonoperating expenses such as interest. The company did benefit from its consumer specialties segment, for which sales rose 48% to $1.3 billion and operating income increased 46% to $268 million.

Of the 16 companies surveyed by C&EN, others whose earnings rose—besides Lubrizol, Cyanamid, and Monsanto—include W. R. Grace (15%), Ethyl (12%), Petrolite (10%), Air Products & Chemicals (7%), and Rohm & Haas (1%).

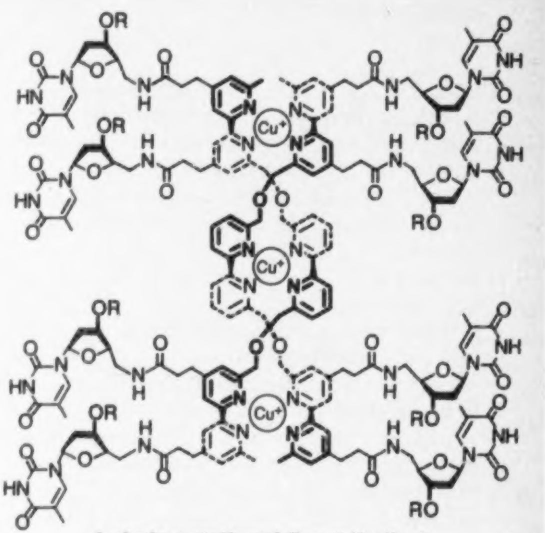
William Storck

Chemical company earnings performance varies widely in second quarter

	SECOND-QUARTER 1990						FIRST-HALF 1990					
			Change from 1989		Profit margin[b]				Change from 1989		Profit margin[b]	
$ Millions	Sales	Earnings[a]	Sales	Earnings	1990	1989	Sales	Earnings[a]	Sales	Earnings	1990	1989
Air Products	$ 712.8	$ 56.8	7%	7%	8.0%	8.0%	$1425.9	$111.1	7%	6%	7.8%	7.9%
American Cyanamid	1228.3	108.4	6	11	8.8	8.5	2380.8	205.3	5	17	8.6	7.8
Arco Chemical	705.0	102.0	−3	−15	14.5	16.5	1390.0	227.0	−2	−4	16.3	16.6
Dow Chemical	4807.0	364.0	4	−50	7.6	15.8	9707.0	826.0	7	−44	8.5	16.2
Ethyl	603.3	57.1	0	12	9.5	8.5	1210.0	109.6	3	7	9.1	8.7
Georgia Gulf	218.7	30.9	−25	−37	14.1	16.9	470.4	68.3	−23	−35	14.5	17.2
B. F. Goodrich	632.5	34.9	1	−34	5.5	8.4	1222.3	51.1	−2	−51	4.2	8.4
W. R. Grace	1628.5	51.3	8	15	3.1	3.0	3135.8	83.9	8	12	2.7	2.6
Hercules	795.8	30.2	1	−27	3.8	5.3	1567.2	63.9	2	−26	4.1	5.6
Lubrizol	357.8	33.1	9	27	9.2	7.9	715.0	62.2	6	10	8.7	8.4
Monsanto	2367.0	247.0	1	2	10.4	10.3	4653.0	441.0	1	−5	9.5	10.0
Olin	660.0	29.0	0	−17	4.4	5.3	1296.0	61.0	−2	−12	4.7	5.2
Petrolite	72.6	3.6	1	10	5.0	4.6	144.6	7.3	0	14	5.0	4.4
Rohm & Haas	768.5	70.0	5	1	9.1	9.4	1462.9	124.1	3	1	8.5	8.7
Union Carbide	2135.0	116.0	−6	−38	5.4	8.2	4308.0	210.0	−5	−46	4.9	8.6
Witco	403.3	18.5	−2	−20	4.6	5.6	798.6	33.0	−2	−18	4.1	5.0

a After-tax, excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales.

French group prepares copper complexes that resemble "inside-out" DNA



Lehn's octathymidino-trihelicate

R = tert-butyldimethylsilyl

Copper complexes that mimic the elegant double-helical structure of DNA but turn the structure inside-out have been prepared for the first time by chemists at Louis Pasteur University in Strasbourg, France. The new molecules, while not themselves DNA, may enable scientists to gain insights into how it interacts with other molecules. Such studies could eventually lead to the development of new drugs that target DNA.

The new molecules, prepared by professor Jean-Marie Lehn and coworkers Ulrich Koert and Margaret M. Harding, consist of an organic "spiral staircase" curling around a column of three or five copper ions. The staircase is fashioned from two intertwined strands of a linear oligomer containing bipyridine units. Attached to each bipyridine unit and flaring outward is a pair of deoxynucleosides, such as deoxythymidine.

In DNA, the deoxynucleosides are inside the double helix and stacking interactions between them hold the two strands together. The overall charge of DNA is negative. In Lehn's molecules, by contrast, the deoxynucleosides are outside the helix and the stacking is between pyridines. The overall charge, due to the copper ions, is positive.

The structure of these so-called nucleohelicates is "strikingly reminiscent of Linus Pauling's original proposal for the structure of DNA," notes coordination chemist Edwin C. Constable of the University of Cambridge, U.K. That proposal, which was later shown to be incorrect, put the deoxynucleosides on the outside and the charged phosphate groups facing in.

Remarkably, the nucleohelicates assemble spontaneously when the bipyridine chains are allowed to interact with copper ions. Scientists aren't sure what drives this spontaneous assembly, although Constable thinks an important controlling factor is the stacking of coplanar pyridine rings.

Lehn has been studying such self-assembling helicates for years, but the new twist is the addition of nucleoside appendages. He says other groups can also be attached to the helix, such as amino acids, sugars, and electroactive and photoactive units.

Lehn's compounds may help shed light on the ways biological molecules are built up and how they recognize and interact with other molecules, Constable says. In particular, the nucleohelicates might be used to probe a new type of molecular recognition—"the recognition of one helix for another helix," he tells C&EN. They "might intercalate or enter into triple-helix hydrogen-bonding interactions with DNA," he notes in a companion article to Lehn's paper in last week's issue of *Nature* [**346**, 339 (1990)]. In addition, double-helical complexes with photoactive metal centers might be developed to target specific nucleic acid sequences on DNA, he says.

Double-helical complexes, which are being studied by several other groups as well, might also be envisioned as a model for a molecular wire, Constable observes. Extended indefinitely, the complex essentially would be a metallic filament encased inside an organic insulator. At least that's "the way I think about it in grant proposals," Constable laughs.

Ron Dagani

Chemical industry in China on rebound

After hobbling through what one Chinese publication calls "a rough and turbulent time" last year and early this year, China's economy and industry and its foreign business ties show signs of bottoming out, according to official figures just issued. However, Chinese and U.S. sources caution, many serious problems remain.

Overall industrial output has started up, with monthly growth rates of 1.4, 2.0, 4.2, and 5.9% in March through June, compared with 1989, and 2.2% growth for the first half of 1990. This follows declines starting last October—down 0.9% in January and February, for example. Afflicted by an austerity program, major infrastructure deficiencies, and world reaction to the political crackdown that began in Beijing's Tiananmen Square on June 4, 1989, China's industrial output grew just 6.8% in 1989, only a third of the 1988 rate (C&EN, Feb. 19, page 6).

Chemical industry led the rebound with a 6.5% increase in the first half, three times higher than industry overall, after also stagnating in January and February. Reflecting the top priority China gives agriculture, fertilizer and pesticides made the most dramatic leaps. China produced 45.9 million metric tons (gross weight) of chemical fertilizer in the first half, up 8.4% from last year's first half, and 119,000 metric tons of pesticides, up 16%, exceeding plan targets by 2.7% and 6.7%, respectively. Of 16 major chemicals, 14 fulfilled their half-year goals.

Foreign investment also rose in May and June, following a decline in the second half of 1989 and through April this year. China approved 530 foreign-funded projects in May with promised foreign capital of $540 mil-

Ethylene Oxide/Glycol Profitability In Doldrums

Prices of oxide and derivatives drop as demand growth slows and supplies rise, spurring antifreeze and polyester sales but hurting profit margins

Bruce F. Greek, C&EN Houston

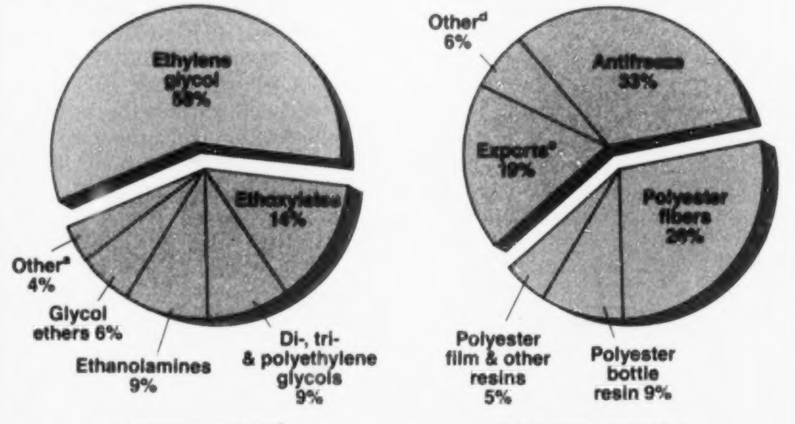
The ethylene oxide and derivative ethylene glycol businesses are in a slump. Supplies are already excessive and planned additions will bring even more capacity on stream during the next three years or so. Behind the current slump is slow growth in demand, but, as is often the case, consumers of antifreeze, polyester, and other products derived from these chemicals are benefitting from much lower prices.

However, lower prices mean smaller margins and thus lower profitability for producers of these major volume ethylene derivatives. Those in the industry generally expect profitability to remain above the low levels of late 1988 and early 1989.

Most ethylene oxide is consumed captively in making derivatives, especially monoethylene glycol. Merchant sales account for only about 10% of production. Almost 60% of the ethylene oxide produced in the U.S. is converted to the glycol. In addition, diethylene and higher glycols and the various ethoxylates account for almost a quarter of ethylene oxide consumption.

The decline in price for ethylene glycol, to about 25 cents per lb, has caused prices of its main end products—antifreeze and polyesters—to fall, increasing sales of the products this year. The lower prices have carried over into the retail sale of antifreeze. For example, antifreeze prices currently are less than half of those last fall. The demand-price elasticity for ethylene glycol during the past year has been clearly reconfirmed, industry sources say.

Ethylene glycol dominates use of ethylene oxide... **...as polyesters dominate use of ethylene glycol**



1990 consumption^b = 6.1 billion lb

1990 consumption (including imports)^b = 5.4 billion lb

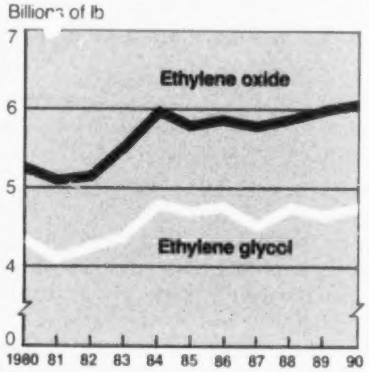
a Includes exports, polyether polyols, tetraethylene glycol, as an intermediate in various products, and as a fumigant/sterilant. b Forecast. c Largely fiber-grade for polyesters. d Solvent, alkyd and polyester unsaturated resins, and as an intermediate for various esters and ethers. **Source:** C&EN estimates

Antifreeze sales appear to be following a pattern seen once in the mid-1970s and again in the early 1980s, says David R. Berlin, antifreeze product manager at First Brands Corp., which in 1986 bought the antifreeze business of Union Carbide. During this cycle, Berlin explains, an apparent shortage of antifreeze develops, consumers stock up, prices rise, demand slumps, and then comes a rebound. In 1988, about 216 million gal of antifreeze were sold, which was nearly an all-time high. In 1989, sales fell to less than 161 million gal, according to the annual survey of the Chemical Specialty Manufacturers Association. Preliminary evidence this year indicates that the expected bounceback is under way, Berlin says, but he declines to forecast what 1990 antifreeze sales will total.

Indeed, forecasting output and demand for ethylene oxide and ethylene glycol is difficult for anybody, considering the volatility of domestic demand for antifreeze and exports of ethylene glycol. Most derivatives of ethylene oxide and uses of ethylene glycol are mature products—except for polyester resins used in bottles and other packaging. Consequently, overall growth rates are low. For example, despite high growth rates for polyester bottle resins, the average annual U.S. growth for ethylene glycol between 1989 and 1997 will be only 1.4%, says M. Peter Bellis, vice president of Chemical Marketing Associates Inc., a Houston-based consulting firm.

In the company's analysis of ethylene oxide and ethylene glycol markets, growth is forecast to be

Ethylene oxide, ethylene glycol output grows slowly



Sources: U.S. International Trade Commission, C&EN estimates

higher for world demand than for U.S. demand alone. During the period 1989 to 1997, world demand for ethylene oxide is forecast to increase 3.5% annually, and for ethylene glycol 4.1% per year, Bellis says. Polyester fiber uses in the Far East and demand for polyester bottle resins in the U.S. and in Europe will lead the growth.

Polyesters eclipsed antifreeze as the largest use of ethylene glycol in the late 1970s and have continued the fast growth. Combined polyester uses will exceed 42% of U.S. glycol demand this year, including exports. If exports are excluded, polyesters account for 52% of the remaining glycol supply.

Among the polyester uses of ethylene glycol, fibers dominate, at 28% of the total demand this year, or two thirds of all polyester demand. Yet, polyester fiber use is increasing more slowly than all other applications.

Bottles and other packaging uses are the fastest growing uses of polyester. Because of the runup of prices in 1988 and 1989, U.S. consumption of these resins grew little, if any, last year, as competing aluminum producers held prices of can stock and as the development of new applications of these resins lagged.

Various ethoxylates, most of which are used as surfactants, are a distant second as a consumer of ethylene oxide. Examples include ethoxylates of phenol, substituted phenols, linear alcohols, and oils. As a group, these derivatives are expected to increase their demand for ethylene oxide at 2.5 to 3% annually, says Wayne H. Peters, business manager for ethylene oxide and derivatives at Shell Chemical. Demand for these and other ethoxylates used as surfactants in detergent formulations will change little, which makes this use aptly fit the definition of a mature end use of ethylene oxide.

Most other uses of ethylene oxide also will grow at about these same rates, says Peters. The derivatives with slowly increasing demand and those made in significant volumes include various ethanolamines, diethylene and higher glycols, and polyols. Glycol ethers are an exception to such growth. Most of these ethers are used as solvents, especially for coatings. Concerns over the emissions and toxicity of some of the ethers, such as ethyl and propyl, are slowly reducing their annual growth to 1 to 2%. Small miscellaneous uses as a group will grow faster, but the effect on total demand is meager.

Demand growth for ethylene oxide this year likely will exceed the capacity added in 1989 through process improvements, thereby helping the average plant operating rate. Demand likely will grow about 100 million lb to 6.1 billion lb, and capacity will be up about 75 million lb to more than 7.2 billion lb. Thus, the average operating rate will rise only slightly from the 84% of nameplate capacity in 1989.

In the future, significant additional ethylene oxide capacity will start up in both the U.S. and Canada. By 1993, U.S. capacity will be more than 8.3 billion lb and Canadian capacity more than 1.4 billion lb, for a combined total of 9.7 billion lb, according to estimates of Marilyn Bradshaw, project leader at Colin A. Houston & Associates, a consulting firm located in Mamaroneck, N.Y. That represents an increase of more than 1.1 billion lb, or 16%, in the U.S., and 600 million lb, or 48%, in Canada from current capacity totals.

The 1993 capacity totals include announced expansions but don't include forecasts for additions achieved through process improvements. Such improvements can add as much as 3 to 5% per year to capacity for products in strong demand, but, if demand for ethylene oxide and ethylene glycol grows as slowly as forecast, these minor additions will be smaller—about what they were in 1989. Also, with the slow demand growth, the industry can expect excess capacity to continue well into the future. □

Ethylene oxide capacity to jump by 1993

Millions of lb	Location	Capacity 1989	1990	1993
U.S.		7140	7215	8350
BASF	Geismar, La.	480	480	480
Dow Chemical	Plaquemine, La.	500	500	500
Hoechst Celanese	Clear Lake, Tex.	550	550	550
Occidental	Bayport, Tex.	570	600	675
Olin	Brandenburg, Ky.	110	110	110
PD Glycol	Beaumont, Tex.	530	530	620
Quantum	Morris, Ill.	220	220	220
Shell	Geismar, La.	825	870	870
Shell (expansion)	Site undisclosed	—	—	450
Sun	Claymont, Del.	110	110	110
Texaco	Port Neches, Tex.	890	890	1000
Texas Eastman	Longview, Tex.	210	210	210
Union Carbide	Seadrift, Tex.	825	825	825
	Taft, La.	1320	1320	1730
CANADA		960	960	1620
Dow Canada	Ft. Saskatchewan, Alberta	405	405	505
Union Carbide	Prentiss, Alberta	400	400	960[a]
	Montreal, Quebec	155	155	155
TOTAL		8100	8175	9970

a May be built in stages; actual completion date undefined. **Sources:** Colin A. Houston & Associates, C&EN estimates

AUGUST 6, 1990

CHEMICAL & ENGINEERING NEWS

Global Investment

Foreign chemical companies keep acquisition pressure on U.S.
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Cover: ICI Americas' western research center in Richmond, Calif., acquired from Stauffer in 1987

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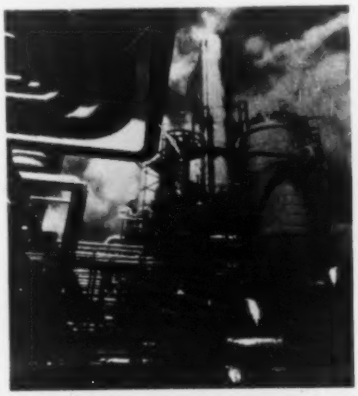

News Focus

Chemical companies worldwide are sorting through their business portfolios seeking to acquire or merge with other firms in order to secure market position, increase market share, or enter new business areas. Page 7

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LETTERS

CHEMICAL SAFETY

Synthesis of nopinone

Recently, we required large quantities of (+) nopinone and opted to synthesize the compound via ozonolysis of (-)-β-pinene, since that protocol is well documented [Boger, D. L., et al., *J. Org. Chem.*, **50**, 1904 (1985); Djerassi, C., Konopelski, J. P., ibid, **45**, 2297 (1980)]. It is well known that ozonolysis of olefins in hydrolytic solvents gives rise to alkyl hydroperoxide intermediates that can be decomposed by a number of reagents [e.g., H_2O, NaI, $(CH_3)_2S$, and $(RO)_3P$]. We chose to use $(CH_3)_2S$ for this decomposition followed by purification by vacuum distillation of the crude nopinone (vide supra). At the end of the distillation, within seconds of releasing the vacuum, the distilling flask exploded, shattering the oil bath. Fortunately, the author sustained only a cut to the side of his forehead (due to the flying glass).

For subsequent preparations, we decided to perform flash chromatography followed by distillation, without incident. We isolated (during chromatography) an impurity that we suspect to be an ozonide. This impurity reacted vigorously when it was being transferred to a vial, and we suspect that it was responsible for the initial explosion during the distillation (note: this impurity could not be detected by the usual peroxide tests). Our suspicions that an ozonide was responsible were supported by Dale Boger, professor at Purdue University, whose group had isolated and characterized an ozonide in their approach (private communication).

In light of the foregoing, it is recommended that researchers exercise appropriate caution when repeating this synthesis.

Patrick M. Gordon
Organix Inc., Woburn, Mass.

Risk of asbestos

Recent articles in several publications have initiated heated debate as well as significant misconception about the risk of asbestos. Almost overnight the pendulum of public perception of asbestos health hazards has swung from great fear to believing that asbestos is a relatively benign substance. Various publications have now referred to removal of asbestos as "fruitless" and an "unwarranted ripoff." The realistic and responsible positioning of the danger of asbestos contamination should be somewhere in between these extreme positions. There had been a general trend toward proposing ad hoc removal of all asbestos. This, in fact, was probably an overreaction. However, there is no scientific doubt that where asbestos is deteriorated or disturbed, people are exposed to a great physical danger.

The current controversy started with the "Harvard Symposium." This "study" has been generally dismissed by the scientific community as lacking sufficient empirical support to reach its conclusions. The one-sided review of previously presented articles was funded by the National Association of Realtors and the Safe Building Alliance. The Safe Building Alliance is a group of former asbestos product manufacturers saddled with huge damage payments from asbestos-related claims. It would appear that these organizations have vested financial interest in this important issue's fading away, regardless of the potential health implications.

Asbestos, when not disturbed, presents no risk unless its fibers are released into the air. Unfortunately, asbestos is easily and often disturbed. Volleyballs hit gym ceilings treated with sprayed-on asbestos, buildings crumble after catching fire, workmen disturb asbestos-contaminated materials within the school or workplace while accomplishing everyday maintenance, and with common building airflow everyone is assured of some amount of dosage. The asbestos removal industry overwhelmingly agrees that a proactive establishment of an in-place management control program is the preferred method to control the release of fibers where asbestos-contaminated materials are not significantly damaged, not likely to be disturbed, or exposure to workers and building occupants is unlikely. However, we also know that children wander

Markets, Strategy Are Driving Worldwide Chemical Investment

U.S. is looking to buy in Western Europe, Europeans are seeking to buy in the U.S., and all are checking the opportunities in Japan; aim is to secure place in growing market, up market share, or enter new business area

Patricia L. Layman, C&EN London

Like playing through cards to work out winning hands, chemical companies large and small are sorting out portfolios of businesses to see, in effect, which cards should be kept, which discarded, and which new cards to draw. In the process, this reshuffling has brought on an increasingly international look and feel to a chemical industry that prides itself on being global.

Companies are increasingly willing to acquire new businesses or merge with other companies in international markets to help secure position in an expanding market, to enhance market share in a particular business, or to enter a completely new business area.

U.S. chemical companies were among the earliest players in the game as they strove to become multinational in the 1960s and 1970s. Their major area of attention was Western Europe. The traumatically difficult times for the petrochemicals industry in Western Europe at the beginning of the 1980s, however, prompted some pulling back. And only in the past few years has there been a resumption of merger and acquisition activities by U.S. companies in Western Europe.

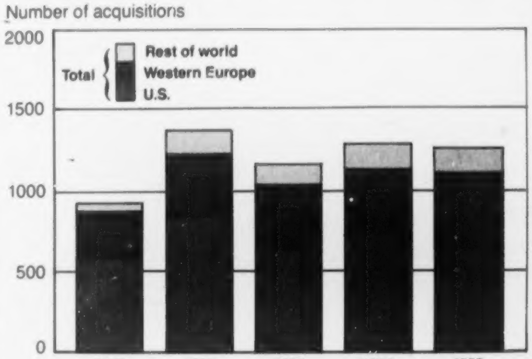
During those same years, however, there has been a signal shift in willingness of European companies to invest outside their own countries. Much of the merger and acquisition activity in Western Europe in the early and mid-1980s was part of the industry's efforts to rationalize, consolidating what were frequently fragmented businesses and cutting capacity where there was a significant overage. Industry analysts say part of the buying and selling game still isn't over—there are still, for example, more than two dozen manufacturers of ethylene in Western Europe compared with far fewer in the U.S. But the rationalization work has slowed.

Now, instead, the view is international and interregional. Chemical companies in non-European Community countries, for example, are seeking to establish positions in the EC prior to the lowering of trade barriers there in 1992. A case in point is the Scandinavian countries. Finland's Neste is buying into or building petrochemical operations in the EC, while Sweden's Nobel Industries is buying companies in various specialty fields. Kemira, also of Finland, and Norway's Norsk Hydro have become the major fertilizer companies in Western Europe by acquiring operations from companies in the EC countries.

Meanwhile, European companies from all over the continent are looking at the U.S. and buying. Some of their deals have been very large—Hoechst's purchase of Celanese, at $2.8 billion, and ICI's acquisition of Stauffer, at $1.69 billion, in turn augmented when ICI sold off parts of Stauffer to Akzo ($625 million) and Rhône-Poulenc ($522 million).

According to data compiled by the mergers and acquisitions team at London-based investment bankers County Natwest, for example, there were 334 chemical deals—acquisitions, stakes, joint ventures, and merg-

U.S. is leading site of chemical acquisitions



Source: Kline & Co.

ers—involving at least one European company in 1987. Of all those, some 55 transactions reported the value, for a total of $15.2 billion. In contrast, the reported value of similar deals in 1988 was $6.19 billion, and in 1989, $6.70 billion.

Many intracountry or intraregion mergers reflect a drive for consolidation in commodity areas, says Alan Norris, assistant director of County Natwest and one of the firm's team. But the newer batches of acquisitions, particularly the international or intercontinental ones, reflect other needs for the companies: the continued drive toward globalization or "critical mass" by the large chemical companies; a shift to specialties and other high-value-added materials; and increased investment in research and development.

Globalization has been an important factor in encouraging acquisitions in the U.S., says John Knight, Norris' colleague at County Natwest. One of the goals for major chemical firms is to be among the five largest producers of their specific products. "To be in the top five globally in a product, you've got to be in the U.S."

Companies consolidating their positions worldwide can often be found in mature markets where economies of scale will bring shutdowns, terminations of workers, and so on. But for companies making acquisitions to enhance strategic development goals, the business area is usually in a growth area. It will be to the buyer's benefit to invest in plants and people, in R&D, and in product development. And if the acquisition takes the buyer into a new geographic region, it will be that much more important to retain good people who know the territory, language, laws, customs, and products.

Such acquisitions will most likely be small and choice, says Norris. "It doesn't surprise me, [with] so many acquisitions less than $25 million. These are in areas that are highly fragmented and due for consolidation—adhesives, for example, or fine chemicals or intermediates. You are not talking about big petrochemicals and commodities, but nice little businesses."

Consultants at Kline & Co., Fairfield, N.J., agree. They say the acquisitions area has always been there, and it's continuing because these are really strategic deals. Companies are buying real value not something that is going to be broken up.

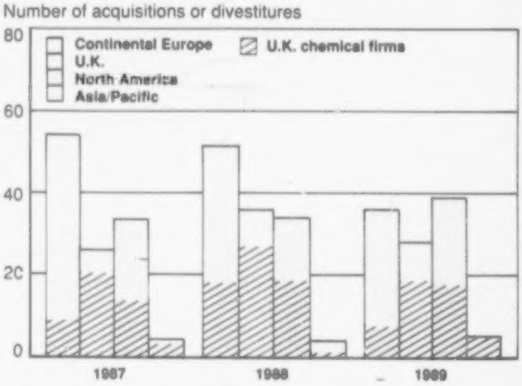
One reason why the U.S. is so attractive an arena in which to do business, besides the sheer size and homogeneity of its marketplace, is that the country's financial structures encourage ongoing reevaluation of the company's hand of cards.

For example, according to Kline, most of the recent acquisitions in the U.S. have resulted from financial reasons, usually pressure on the sellers, although occasionally on the part of the buyer.

Many of these asset sales were driven financially because the companies that owned these businesses had to restructure somehow, someway, either to improve stock performance or to fend off corporate raiders.

Says one Kline manager: "If you look at the bigger deals, the [purchasers] have been more strategic, and the foreign firms are willing to pay higher prices due to strategic considerations to get the U.S. market positions that they desire."

Among West Europeans, U.K. chemical firms active in acquisitions, divestitures



Source: County Natwest investment bank, London

To some extent, the U.K. financial structure is similar to that of the U.S., and business attitudes tend to be similar, as well. For example, say Knight and Norris of the County Natwest team, their data show it is much easier for companies to do deals in the U.K. than elsewhere in Europe. Norris points out that last year European chemical buyers made 28 purchases or divestments just in the U.K., compared with 36 in all the rest of Western Europe.

The British companies, he suggests, tend to see their businesses as a portfolio of assets—an attitude only beginning to really take hold among chemical companies on the continent. He and Knight cite, for example, BASF's announcement that it is working with New York investment bank Wasserstein Perella & Co. to arrange the sale of its fragrances and flavors division, Fritzsche Dodge & Olcott, and with bankers Morgan Stanley to sell its inks division, as an indication of strategic portfolio thinking.

At Akzo, of the Netherlands, portfolio management is also significant. Aarnout A. Loudon, chairman of the company, said at Akzo's annual meeting in April, "With the acquisition of Reliance, we have realized our highest priorities concerning the strengthening of our core businesses and the geographic distribution of our activities. Also, we will continue to evaluate our business portfolio critically. This may lead to further divestments although we are not contemplating any major divestments."

In addition to the financial structures, another factor discouraging many chemical purchases in Western Europe is the lack of publicly held small to medium-size companies. Big pools of medium-size companies such as those in the U.S. don't exist in Europe. There are fewer there because before the companies achieve that size, the bigger firms buy them up.

Moreover, company stock is often structured in such a way that hostile bids are virtually impossible. A case in point is West Germany's Henkel, a family-owned company which in the mid-1980s sold some shares to the public. Roughly 15% of the company's shares are now traded—but all are nonvoting shares. As one analyst puts it, "Konrad Henkel hasn't given up anything and still has control over Henkel. Unless the ownership wants to sell, there is no way you can raid these companies." Persuasiveness thus becomes a prime virtue for acquisition negotiators: persuasiveness and patience, particularly when making a cross-border acquisition into continental Europe.

Speaking at a recent financial conference in London, David Margetts, chief executive of the building chemicals division of U.K.'s Laporte Group, said: "It will take two or three times as long as you imagine and more time than completing a similar deal in the U.S. or Britain. You can't pick it up and then drop it the next day." Instead, he added, the president or other senior executive of the company wishing to make the acquisition must find time in the schedule to maintain the momentum of the deal.

The need for patience is also pointed out by David Fyfe, group managing director of the U.K.-based high-value fine and research chemicals manufacturer, MTM. The firm has more than tripled its corporate sales primarily by way of small acquisitions since 1985. Sales in 1985 were less than £20 million; this year they will probably top £90 million, roughly $165 million.

According to Fyfe, MTM's early acquisition goals were to gain U.S. manufacturing capacity: at least one third of the market for these research and fine chemicals is in the U.S. and, "if you're going to be anything, you must have the capacity to offer to the U.S. Besides, U.S. companies still prefer U.S. suppliers."

Other acquisitions were made to broaden the product slate and the geographical coverage throughout Western Europe; MTM also has established technological cooperation pacts in Eastern Europe. Yet another reason—crucial for a smaller company, Fyfe says—is for the talents of the people in the acquired companies.

"When you are a small, fast-growing company, human resourcing is crucial, almost growth limiting," he says. "If you can buy a core of management as well as production, you're two steps ahead."

He concedes an obvious point: "We can never get in an auction war with a big company. Instead, we specialize in ferreting out a company, privately owned, which the owner has not put on the market, where he can be sold the benefits of cashing in now and taking long-term management with an entrepreneurial company like us. Quite often," he adds, "it is a long courtship—for example, one was for 18 months before it was finally agreed."

The ability to make a decision quickly is another plus. According to Fyfe, his company has gained "a reputation as a serious [purchaser] and a fast closer—as you say in America, we don't screw around once we decide we want a company."

At the other end of the size spectrum, executives at British chemicals giant ICI make similar points about credibility and speed of decision.

John Dewhurst, acquisitions manager at ICI, says his group becomes involved at the request of a business unit or the corporate directors. "It is fed back to us—'we want you to buy a large company in France because' ... for example. We're searching all the time, meeting regularly with all sorts of people, explaining our philosophy and strategies." Moreover, in each country, there is an arm of ICI, "and they are looking also. We want a balanced portfolio, to reflect how big we want to be in this business, or the correct geographic spread."

"We developed a set of credentials," Dewhurst says. "Now, a company will know we will give a prompt response, either over the phone or within three days. Anyone who approaches us knows we move fast. We are serious, we don't go on fishing trips. If we don't want it, we don't get the data. When we start off, we are serious."

In fact, although the company has hit the headlines for its blockbuster acquisitions, ICI has made about 45 transactions a year—both acquisitions and divestments—during the five years the acquisitions group has existed. "We apply the same criteria to all of them, to get things done," says Dewhurst. "Over the last two years, we have been doing more divesting and are now almost in balance, getting out of businesses we no longer want to be in." One of the most telling results, as he sees it: About one out of every seven or eight people in ICI have been taken on during the past five years.

Ironically, given the major inroads made by Japanese companies in industries such as automobiles and electronics, Japan is for the most part absent from chemical industry merger and acquisition activity.

Consultants agree it is difficult for western companies to invest directly in Japan, although one leading Japanese businessman believes this situation is changing. And it is still rare to see Japanese chemical companies making acquisitions in the West, although they are beginning to take more of a part in joint ventures.

And although there have been only a relatively limited number of Japanese purchases of chemical companies in the U.S. or in Western Europe, that is not because of lack of interest. Teams from U.S. and European investment banks are setting up ventures with their Tokyo counterparts so as to represent the Japanese companies that are interested in looking for business opportunities outside Japan.

Most overseas acquisition spending by U.S. chemical firms is in West Europe

$ Millions	1989	1988	1987
U.K.	—	$ 431	—
France	$ 1,143	302	$ 116
West Germany	645	182	—
Total Western Europe	**9,410**	**1640**	**3466**
Japan	1,114	—	—
Total Asia/Pacific	**1,559**	**852**	—
TOTAL ALL COUNTRIES	**$11,005**	**$2918**	**$4041**

Sources: U.S. Department of Commerce, Survey of Current Business

The early entrée for Japanese companies, says County Natwest's Norris, will be in downstream chemical businesses.

"Japanese companies are moving in very slowly in downstream areas to support their auto/electronics industries. They are starting in small joint ventures—in plastics processing, for example. That's where they are putting their money."

Shigekuni Kawamura, president of Dainippon Ink & Chemicals, basically agrees with that assessment—and the firm has been one of the few active Japanese international purchasers on the chemical scene in the past couple of years.

When he spoke at the annual meeting of the European section of the Society of Chemical Industry held last October, Kawamura commented on the absence of a takeover culture in Japan. "Because of the strong bond of unity between the company and its employees, it is very difficult for Japanese companies to carry out a takeover in their home market. It would almost be like trafficking in the lives of human beings. This is one reason why the companies in the Japanese market are more concerned about market share than profit."

On the other hand, Kawamura added, acquisitions and mergers are considered part of standard operating procedure for western firms. It would be easier for a western chemical firm to make an acquisition in Japan than for one Japanese firm to buy another, he said.

Eventually, however, he suggested that other companies would reach the same conclusions that Dainippon reached when it decided to make its bids for Sun and Reichhold. Besides a defensive measure to protect its Japanese markets for inks and resins, "these takeovers were also undertaken because of our realization that the world is becoming more and more economically unified"—and more homogeneous in style and standard of living and level of technological advancement. Dainippon "decided it could not be satisfied with its position in the Japanese market alone," he said.

Kawamura also noted, "Japanese companies are blessed with stockholders who have a long-term perspective." The blessing can be just as important for the

Europeans have been most active purchasers, but tend to stay close to home

	NUMBER OF ACQUISITIONS												
	Total	1989				1988				1987			
Company (country)	1987–89	U.S.	Europe	Other	Total	U.S.	Europe	Other	Total	U.S.	Europe	Other	Total
Elf Aquitaine[a] (France)	46	5	12	3	20	2	10	1	13	5	6	2	13
Airgas (U.S.)	35	15	—	—	15	8	—	—	8	12	—	—	12
Akzo (Netherlands)	33	6	4	2	12	4	3	4	11	4	4	2	10
Rhône-Poulenc (France)	31	5	3	2	10	4	4	5	13	1	5	2	8
Montedison (Italy)	26	2	5	3	10	2	5	1	8	4	4	—	8
ICI[b] (U.K.)	25	4	5	3	12	3	3	7	13	—	—	—	—
Du Pont (U.S.)	24	4	4	1	9	5	3	—	8	6	1	—	7
Unilever (U.K./Netherlands)	22	8	12	2	22	—	—	—	—	—	—	—	—
Courtaulds (U.K.)	21	6	4	2	12	—	—	—	—	3	6	—	9
Laporte Group (U.K.)	19	5	1	2	8	5	3	3	11	—	—	—	—
W. R. Grace (U.S.)	15	—	—	—	—	6	1	—	7	6	1	1	8
Borden (U.S.)	15	—	—	—	—	1	4	3	8	7	—	—	7
Nobel Industries (Sweden)	15	—	8	—	8	—	7	—	7	—	—	—	—
Norsk Hydro[c] (Sweden)	15	1	5	2	8	2	4	1	7	—	—	—	—
Shell Group (U.K./Netherlands)	14	1	3	3	7	2	4	1	7	—	—	—	—
Hoechst[d] (West Germany)	13	3	7	3	13	—	—	—	—	—	—	—	—
Cookson Group (U.K.)	10	—	—	—	—	6	3	1	10	—	—	—	—
BASF (West Germany)	9	—	—	—	—	2	3	4	9	—	—	—	—
Henkel (West Germany)	8	—	—	—	—	—	—	—	—	3	4	1	8
Perstorp (Sweden)	8	—	—	—	—	—	—	—	—	—	8	—	8
Air Products (U.S.)	8	—	—	—	—	3	4	1	8	—	—	—	—
Dainippon Ink & Chemicals (Japan)	8	2	4	2	8	—	—	—	—	—	—	—	—
H. B. Fuller (U.S.)	7	—	—	—	—	4	2	1	7	—	—	—	—
Lilly Industrial Coatings (U.S.)	7	7	—	—	7	—	—	—	—	—	—	—	—
Solvay (Belgium)	7	1	3	3	7	—	—	—	—	—	—	—	—

a Includes Sanofi, controlled by Elf. b Includes ICI Australia, controlled by ICI. c Includes subsidiary Dyno Industries. d Includes Roussel-Uclaf, controlled by Hoechst.
Source: Kline & Co.

Biggest acquisitions of late 1980s were in the U.S.

Seller (country)	Buyer (country)	Business sector	Purchase price ($ millions)
1987			
Sohio (U.S.) 45% outstanding	British Petroleum (U.K.)	Petroleum, chemicals	$ 7,600
Chesebrough-Ponds (U.S.)	Unilever (U.K./ Netherlands)	Personal products, chemicals	3,100
Celanese (U.S.)	Hoechst (West Germany)	Chemicals, fibers	2,800
Stauffer (U.S.)	ICI (U.K.)	Chemicals	1,690
Himont (U.S.)	Montedison (Italy)	Polypropylene	1,490
Stauffer (ex-ICI)	Akzo (Netherlands)	Specialties	625
Union Carbide (U.S.)	Rhône-Poulenc (France)	Agrochemicals	575
Feldmuehle Nobel (West Germany)	Veba (West Germany)	Chemicals, plastics	555
Stauffer (ex-ICI)	Rhône-Poulenc (France)	Basic chemicals	522
1988			
Sterling Drug (U.S.)	Eastman Kodak (U.S.)	Drugs, fine chemicals	5,100
Borg-Warner (U.S.)	General Electric (U.S.)	ABS, other plastics & chemicals	2,310
Cain Chemical (U.S.)	Oxy Petroleum (U.S.)	Petrochemicals	2,100
Koppers (U.S.)	Beazer (U.K.)	Chemicals	1,720
Staley (U.S.)	Tate & Lyle (U.K.)	Corn-based chemicals	1,500
Polysar (Canada)	Nova (Canada)	Petrochemicals	1,300
Deutsche Texaco (West Germany)	RWE (West Germany)	Petrochemicals	1,230
Cooper (U.S.)	Bayer (West Germany)	Diagnostics	500
1989			
SmithKline (U.S.)	Beecham (U.K.) merger	Drugs	16,000
Squibb (U.S.)	Bristol-Myers (U.S.)	Drugs	11,500
American Home Products (U.S.)	A. H. Robins (U.S.)	Drugs	3,170
Marion Labs (U.S.) 67%	Dow Chemical (U.S.)	Generic drugs	3,155
Dutch government	DSM (Netherlands) 67% public shareholders	Plastics, chemicals	1,350
Atlantic Richfield (U.S.)	Lyondell Petrochemicals 54% public shareholders	Petrochemicals	1,300
Pennwalt (U.S.)	Elf Aquitaine (France)	Specialty chemicals	1,240
Spanish government	Repsol, 23%—public shareholders	Petrochemicals	1,000
Connaught (Canada)	Institut Merieux (France)	Vaccines	796[a]
RTZ (U.K.)	Rhône-Poulenc (France)	Surfactants	894
Emery (U.S.)	Henkel (West Germany)	Oleochemicals	500
1990			
Nova (Canada)	Bayer (West Germany)	Synthetic rubber	845[a]

[a] In U.S. dollars; $1.00 U.S. = $1.184 Canadian. **Sources:** County Natwest investment bank, London; Kline & Co.

acquired company. For example, Kratos, a U.K. maker of mass spectrophotometers and other analytical instruments, was acquired in early 1989 by Shimadzu, Japan's largest producer of analytical equipment. According to John Waldron, chairman of Kratos, Shimadzu is taking a long-term view of how the firm fits with the parent.

"Their approach has been, 'How can we help you?' They have taken a lot of time and trouble to try to understand our business and about how a western company operates. There is a feeling of permanence," Waldron says. That must come as a relief to a firm that has, over several decades, been variously controlled by two large U.K. industrial companies, a U.S. high-tech business, a group of U.K. bankers, and finally Shimadzu.

Whatever the acquiring company, there are questions that must be asked. The most basic, indeed, is: "Is this a daft idea, or is it a runner?" says Geoffrey Pyke, director of the financial practices unit in Chem Systems International, in London. From there, a company must refine the considerations: How serious are the downside risks? What is the profit outlook? What is the value? Will the business stay running for another 10 years? Or will it take rehabilitation money, and if so, how much?"

Analysis of the business is crucial, agrees David R. Wallis, director of commercial development at PPG Industries. PPG, which has made several specialty acquisitions in Western Europe, turned the job over to its commercial development department in recognition of the need for a single department to bring its expertise to bear in acquisitions. "People in a group doing this once every 10 years simply won't have the expertise to know they will touch all the bases," Wallis points out.

In international acquisitions, "our experience would say that simply because the deal is foreign, that by itself doesn't create more problems or opportunities. We are largely focused on strategic businesses—there are not a great number of acquisition opportunities in Europe. We tend to know those businesses. Our people in the locations identify the opportunities where they want to expand their business. We also receive inquiries from investment bankers and similar groups, where a business is strategic and we would be a logical buyer.

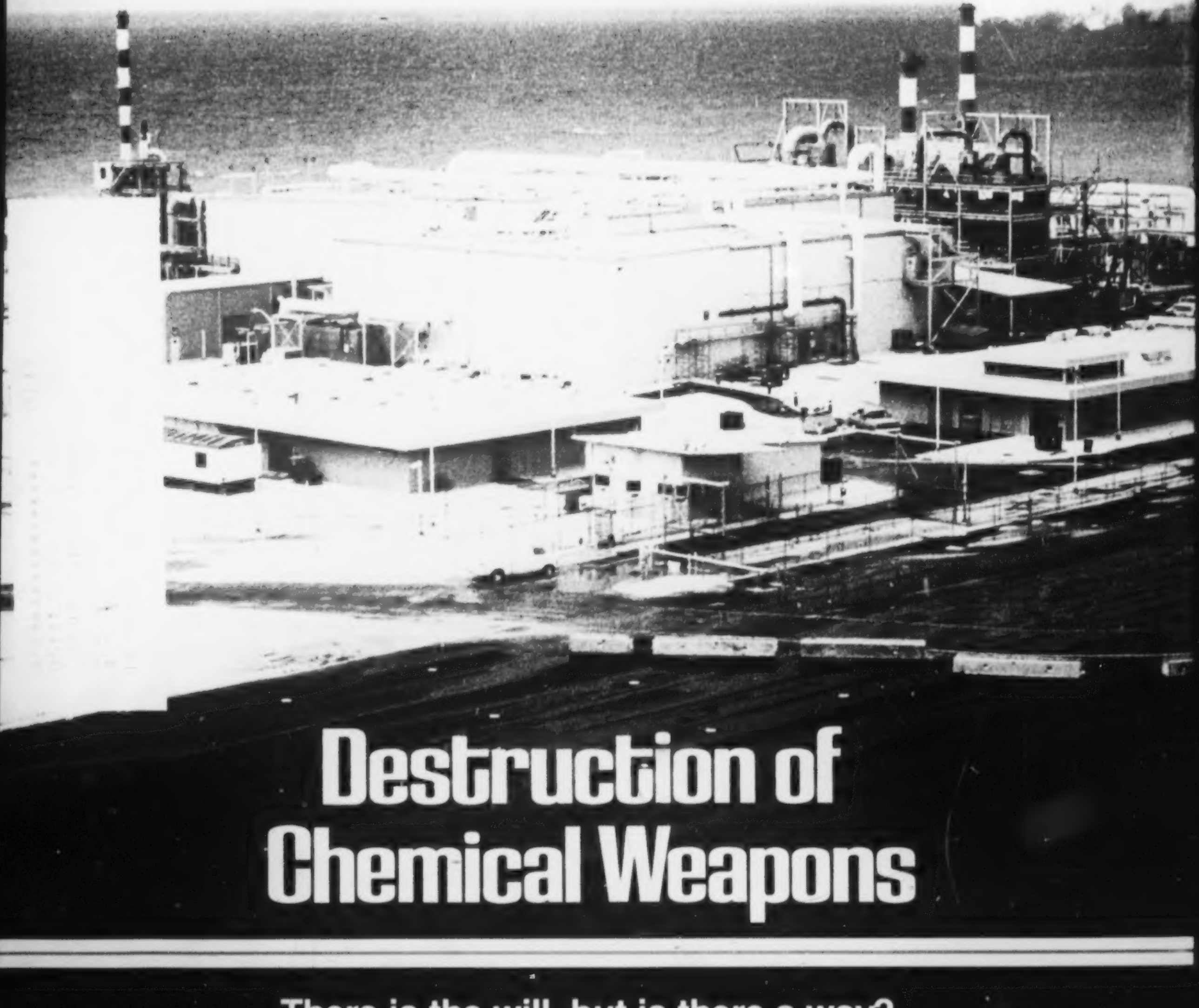
"What has driven our offshore investment are the opportunities to exploit our technology, where we have world-class technology, and where we have global customers. The customer has driven it; technology has driven it; and the opportunity was there." □

Chemical company earnings generally drop during second quarter Page 22

AUGUST 13, 1990

CHEMICAL & ENGINEERING

NEWS



Destruction of Chemical Weapons

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Cover: U.S. chemical weapons disposal facility at Johnston Atoll in Pacific Ocean. Photo courtesy of the Army

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Business

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Government

The Clean Air Act amendments and the five-year farm bill reauthorization are slated for action by Congress when it reconvenes after Labor Day. **Page 28**

Science/Technology

AUTONOM, new computer software developed at West Germany's Beilstein Institute, uses IUPAC rules to provide names for graphic chemical structures. **Page 31**

Scientists are optimistic that factors preventing the production of ethylene from natural gas will soon be overcome. **Page 32**

News Focus

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LETTERS

CHEMICAL SAFETY

Piranha solution explosions

A letter by Daniel Dobbs, Robert Bergman, and Klaus Theopold (C&EN, April 23, page 2) describes two explosions associated with "piranha solution" (30% H_2O_2 and concentrated H_2SO_4 mixed in equal volumes). These incidents call for further comment.

One of the incidents involved the use of an H_2O_2/H_2SO_4 mixture and acetone in a cleaning procedure. It should be pointed out that even in the absence of sulfuric acid, mixtures of acetone and hydrogen peroxide can give rise to the formation of a shock-sensitive organic peroxide. A number of explosions have occurred in this way. As the world's largest manufacturer of peroxygen chemicals, Interox strongly advises taking every precaution to prevent even inadvertent mixing of hydrogen peroxide and acetone. In this case, the presence of sulfuric acid would have tended to increase the hazard; sulfuric acid can (in effect) activate hydrogen peroxide toward reaction with most organic compounds. The described cleaning procedure is clearly hazardous and should not be used.

In the second incident, a bottle of H_2O_2/H_2SO_4 mixture exploded after standing for a week. The authors of the letter state that the bottle was, to their knowledge, loosely capped. They further state that "the force of the detonation makes it seem likely to us that it was due to a chemical reaction rather than simply to the buildup of pressure in the container." Although it is impossible to be sure without more detailed information, the damage described (destroyed bottles) does not seem inconsistent with what might be expected if an H_2O_2 / H_2SO_4 solution was inadvertently sealed. Even moderate confinement can lead to a surprisingly powerful pressure burst. We know of incidents in which stoppered glass volumetric flasks containing 1% H_2O_2 were shattered by the slow evolution of oxygen. We recommend the use of vented caps on all bottles containing peroxygen solutions.

Piranha solution is a powerful oxidant and should never be used casually or without a detailed understanding of the possible hazards. However, these incidents should be interpreted in light of the fact that H_2O_2/H_2SO_4 mixtures are widely (and safely) used in industry—particularly in semiconductor chip manufacturing.

C. Vance Erickson
Interox America
Deer Park, Tex.

Community of scholars

John P. Sevanair's pessimistic assessment of the recruitment value of undergraduate research (C&EN, April 23, page 74) compels me to respond, although I expect he will dismiss this as simply another personal anecdote. (I wonder how many such anecdotes are needed to constitute good evidence?)

I was a sophomore math major at the University of Notre Dame when I was attracted to undergraduate research in inorganic chemistry. The great time some of my peers were having as part of Bob Scheidt's "undergraduate army" convinced me I should find out what I was missing. It turned out to be hard work, long hours, close friendships, intellectual fulfillment, and lots of fun. I became a chem major, and later a physical chemist. I now teach, do research, and direct the research of graduate and undergraduate students.

The subculture to which I was exposed while working in the lab, attending research seminars, and hanging around the chem building at all hours of the day and night appealed to me strongly. It was this undergraduate experience that led me to pursue chemistry, and no amount of good teaching in the classroom could have done it, nor could bad teaching have dissuaded me.

I do not mean to deny the importance of good teaching. The current reaffirmation of its value, even at large research institutions, has been, in my opinion,

Continued on page 47

Correction

• July 16, page 35: Solomon H. Snyder has published more than a 1000 scientific articles since getting his M.D. in 1962, rather than 100.

Chemical Earnings Continue Downward Trend in Second Quarter

William J. Storck,
C&EN Northeast News Bureau

U.S. chemical earnings continued their downward trend in the second quarter as falling prices and lackluster demand hit profitability.

C&EN's quarterly survey of chemical earnings shows a double-digit decline at chemical and oil companies, but improvement at diversified firms that produce chemicals and at drug manufacturers for the quarter.

At 30 chemical companies regularly surveyed by C&EN, total earnings declined for the fourth straight quarter. These firms had total earnings for the quarter of $1.62 billion, down 24% from the same period in 1989. At the same time, sales rose 3% to $21.8 billion for the 30 chemical firms. As a result, profit margins fell to an average 7.4% from 10.0%.

A disquieting fact is that in the second quarter, which historically shows good growth from the first, earnings for the 30 companies improved only 3% from the January through March period of this year. However, sales grew almost 8% on a quarter-to-quarter basis.

For the first six months, combined earnings at the 30 companies fell 25% to $3.20 billion on sales growth of 3% to $43.3 billion. Profit margins fell to an aggregate 7.4% from 10.1% in the first half of 1989.

As in past quarters, demand in major markets caused problems. Again, autos and housing continued their relatively poor performance, leading to, at best, flat demand for chemicals in these sectors.

More than half of the decline in chemical earnings in the quarter, came at Dow Chemical, where earnings fell 50% from year-earlier levels to $364 million. Without Dow, the

Chemical industry leaders for the second quarter . . .

Sales				Earnings[a]			Profitability		
Rank 1990		$ Millions	Rank 1989		$ Millions	Rank 1989		Earnings as % of sales	Rank 1989
1	Dow Chemical	$4807.0	1	Dow Chemical	$364.0	1	International Flavors	18.1%	1
2	Monsanto	2367.0	2	Monsanto	247.0	2	Arco Chemical	14.5	4
3	Union Carbide	2135.0	3	Union Carbide	116.0	3	Georgia Gulf	14.1	3
4	W. R. Grace	1628.5	4	American Cyanamid	108.4	5	Great Lakes Chemical	13.5	5
5	American Cyanamid	1228.3	5	Arco Chemical	102.0	4	Loctite	12.6	7
6	Hercules	795.8	6	Rohm & Haas	70.0	6	Vista Chemical	11.2	2
7	Rohm & Haas	768.5	7	Ethyl	57.1	9	Betz Laboratories	11.1	10
8	Air Products	712.8	10	Air Products	56.8	7	Nalco Chemical	11.0	9
9	Arco Chemical	705.0	8	W. R. Grace	51.3	12	Monsanto	10.4	11
10	Olin	660.0	11	International Flavors	45.9	14	Ethyl	9.5	13

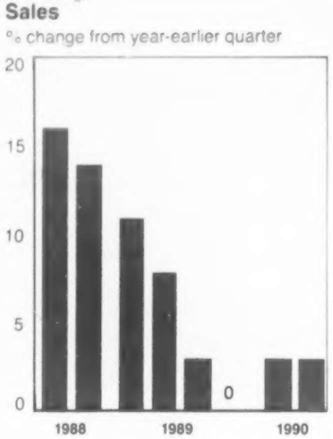
. . . and for the first six months of 1990

Sales				Earnings[a]			Profitability		
Rank 1990		$ Millions	Rank 1989		$ Millions	Rank 1989		Earnings as % of sales	Rank 1989
1	Dow Chemical	$9707.0	1	Dow Chemical	$826.0	1	International Flavors	17.7%	2
2	Monsanto	4653.0	2	Monsanto	441.0	2	Arco Chemical	16.3	5
3	Union Carbide	4308.0	3	Arco Chemical	227.0	4	Georgia Gulf	14.5	2
4	W. R. Grace	3135.8	4	Union Carbide	210.0	3	Great Lakes Chemical	13.5	1
5	American Cyanamid	2380.8	5	American Cyanamid	205.3	5	Loctite	12.2	7
6	Hercules	1567.2	6	Rohm & Haas	124.1	6	Butz Laboratories	10.9	8
7	Rohm & Haas	1462.9	9	Air Products	111.1	8	Nalco Chemical	10.7	9
8	Air Products	1425.9	10	Ethyl	109.6	11	Vista Chemical	10.0	4
9	Arco Chemical	1390.0	8	International Flavors	87.5	13	Monsanto	9.5	10
10	Olin	1296.0	11	W. R. Grace	83.9	14	Ethyl	9.1	12

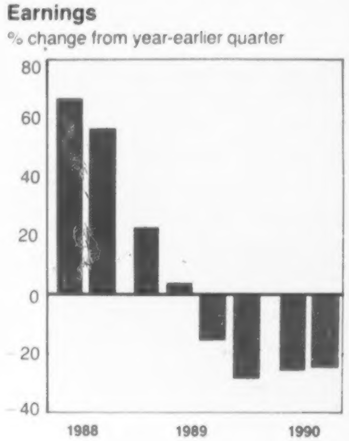
Note: Based on 30 chemical companies listed on page 24. a After taxes.

Chemical industry second-quarter 1990 results

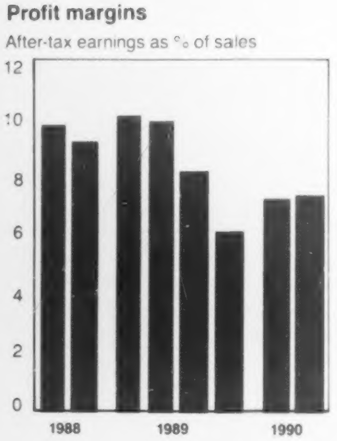
- Sales were up 3%
- Earnings dropped 24%
- Profit margins were 7.4%
- Production increased 1.7%
- Prices declined 1.8%


Sales

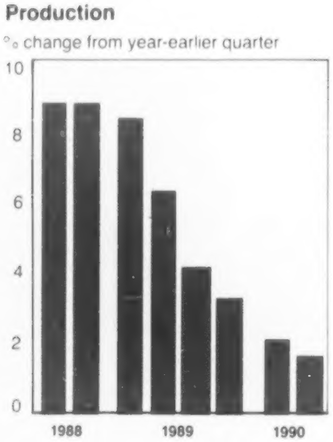
% change from year-earlier quarter


Earnings

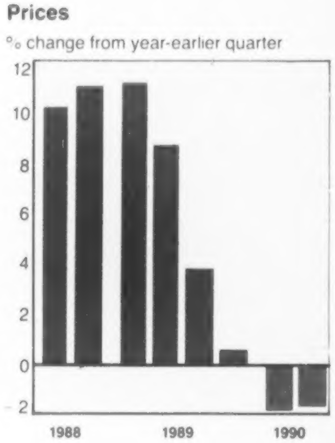
% change from year-earlier quarter


Profit margins

After-tax earnings as % of sales

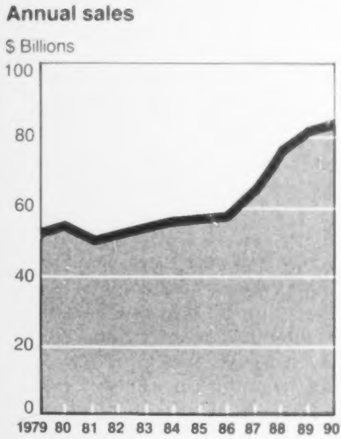

Production

% change from year-earlier quarter

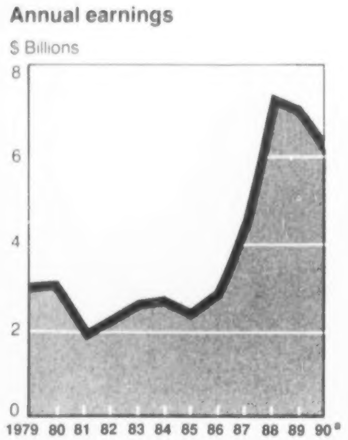

Prices

% change from year-earlier quarter

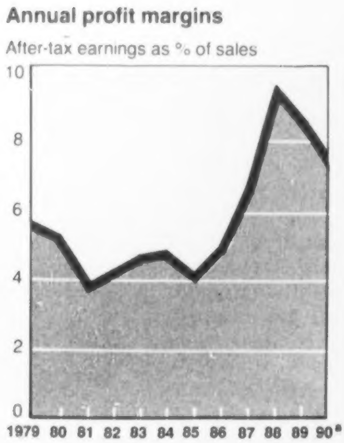
Sales in 1990 likely to rise about 2% as earnings drop 15%, lowering profit margins to about 7.2%


Annual sales

$ Billions


Annual earnings

$ Billions


Annual profit margins

After-tax earnings as % of sales

Note: All sales, earnings, and profit margin data are based on 30 chemical companies listed on page 24. a C&EN estimates

Earnings and profitability dropped for chemical companies in the second quarter

	SECOND-QUARTER 1990						FIRST-HALF 1990			
	Sales	Earnings[a]	Change from 1989		Profit margin[b]		Sales	Earnings[a]	Change from 1989	
	($ millions)		Sales	Earnings	1990	1989	($ millions)		Sales	Earnings
Air Products	$ 712.8	$ 56.8	7%	7%	8.0%	8.0%	$ 1,425.9	$ 111.1	7%	6%
American Cyanamid	1,228.3	108.4	6	11	8.8	8.5	2,380.8	205.3	5	17
Arco Chemical	705.0	102.0	−3	−15	14.5	16.5	1,390.0	227.0	−2	−4
Betz Laboratories	147.6	16.4	13	17	11.1	10.8	290.9	31.8	14	17
Cabot	421.0	16.3	−11	70	3.9	2.0	876.1	31.3	−13	−15
Chemed	151.4	5.4	0	−26	3.5	4.8	265.3	9.6	−9	−24
Crompton & Knowles	98.4	5.3	3	17	5.4	4.7	192.7	9.4	5	20
Dow Chemical	4,807.0	364.0	4	−50	7.6	15.8	9,707.0	826.0	7	−44
Ethyl	603.3	57.1	0	12	9.5	8.5	1,210.0	109.6	3	7
First Mississippi	146.6	0.8	7	def	0.5	def	263.5	2.1	3	−65
H. B. Fuller	204.7	6.3	4	28	3.1	2.5	386.2	7.9	3	16
Georgia Gulf	218.7	30.9	−25	−37	14.1	16.9	470.4	68.3	−23	−35
B. F. Goodrich	632.5	34.9	1	−34	5.5	8.4	1,222.3	51.1	−2	−51
W. R. Grace	1,628.5	51.3	8	15	3.1	3.0	3,135.8	83.9	8	12
Great Lakes Chemical	256.5	34.5	33	11	13.5	16.2	508.8	68.8	51	15
Hercules	795.8	30.2	1	−27	3.8	5.3	1,567.2	63.9	2	−26
Imcera Group	402.8	27.8	51	−35	6.9	16.0	774.5	46.5	48	−30
International Flavors	253.9	45.9	7	11	18.1	17.5	495.3	87.5	7	9
Loctite	139.2	17.6	15	9	12.6	13.3	273.1	33.4	15	10
Lubrizol	357.8	33.1	9	27	9.2	7.9	715.0	62.2	6	10
Monsanto	2,367.0	247.0	1	2	10.4	10.3	4,653.0	441.0	1	−5
Morton International	429.1	30.5	28	31	7.1	6.9	876.2	69.6	19	20
Nalco Chemical	301.6	33.1	13	12	11.0	11.1	586.4	62.8	13	15
Olin	660.0	29.0	0	−17	4.4	5.3	1,296.0	61.0	−2	−12
Petrolite	72.6	3.6	1	10	5.0	4.6	144.6	7.3	0	14
Quantum Chemical	586.0	7.1	−13	−85	1.2	6.8	1,268.8	12.9	−15	−89
Rohm & Haas	768.5	70.0	5	1	9.1	9.4	1,462.9	124.1	3	1
Union Carbide	2,135.0	116.0	−6	−38	5.4	8.2	4,308.0	210.0	−5	−46
Vista Chemical	182.9	20.4	−10	−42	11.2	17.3	366.7	36.6	−9	−46
Witco	403.3	18.5	−2	−20	4.6	5.6	798.6	33.0	−2	−18
TOTAL[c]	**$21,817.7**	**$1620.2**	**3%**	**−24%**	**7.4%**	**10.0%**	**$43,312.0**	**$3195.1**	**3%**	**−25%**

a After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. c For 30 companies reporting.

remaining 29 firms would have shown an average decline of 10%.

Dow attributed its large decline to many things, including lower prices and higher costs. The company says anticipated price increases did not materialize and overall pricing levels slipped from the first quarter and from the year-earlier quarter. Also, the company says manufacturing costs were up 3% in spite of declining feedstock and energy costs, resulting from extended plant maintenance shutdowns and production outages in several major facilities.

In another case of things not always being what they seem, of the 30 companies, only 12 had earnings declines, although all of these were in double digits. This certainly does not indicate a full-blown chemical recession, but it is worrisome in that, unless the fundamentals change, the downward trend could spread further through the industry as it did in the early 1980s.

The remaining firms for the most part showed moderate sales growth for the quarter. And, in spite of the decline in both earnings and profit margins, profitability remains relatively high. On a historical basis, the industry was at about 7.5% in the first quarter of 1980 and did not reach that level again until about the first quarter of 1987. And it is only since 1988 that the chemical industry started seeing the high profit margins that it seems to have become accustomed to.

Within the chemical industry, the economics are fairly flat. Production of chemicals and products, according to government data, rose only 1.7% from the same quarter a year ago, but was essentially flat when compared with the first quarter.

Prices for chemicals and allied

FIRST-HALF 1990		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1989		Profit margin[b]	
1990	1989	Sales	Earnings	1990	1989
7.8%	7.9%	6%	−5%	7.7%	8.5%
8.6	7.8	1	−7	6.3	6.9
16.3	16.6	−8	−20	15.1	17.3
10.9	10.7	14	15	10.9	10.8
3.6	3.6	−9	−32	2.6	3.5
3.6	4.3	1	1	3.9	3.9
4.9	4.3	2	16	6.6	5.8
8.5	16.2	4	−33	10.1	15.6
9.1	8.7	6	−3	9.2	10.1
0.8	2.3	15	−73	0.9	3.8
2.0	1.8	5	−4	2.2	2.4
14.5	17.2	−18	−27	16.1	18.1
4.2	8.4	−5	−48	4.9	9.0
2.7	2.6	7	18	3.4	3.0
13.5	17.7	56	16	13.7	18.5
4.1	5.6	8	−50	2.2	4.6
6.8	12.7	44	−19	4.5	8.0
17.7	17.2	7	9	16.2	15.8
12.2	12.7	12	13	12.0	11.9
8.7	8.4	6	−3	7.8	8.5
9.5	10.0	2	0	7.1	7.3
7.9	7.9	17	6	7.9	8.7
10.7	10.6	11	17	11.2	10.7
4.7	5.2	−1	6	4.7	4.4
5.0	4.4	1	41	4.8	3.4
1.0	7.9	−21	−85	2.1	10.8
8.5	8.7	3	−17	6.6	8.2
4.9	8.6	−3	−45	5.3	9.3
10.0	16.9	−8	−43	10.3	16.7
4.1	5.0	−2	−16	4.3	5.1
7.4%	**10.1%**	**2%**	**−25%**	**7.2%**	**9.8%**

def = deficit.

products for the second quarter declined an average of 1.8% from the second quarter of 1989, but they increased a slight 0.4% from the first quarter. Prices for the large-volume industrial chemicals fell 5.3% compared with the year-earlier quarter and were off about 1.2% against the first quarter of this year.

It is, of course, these large-volume commodity industrial chemicals that weigh so heavily on the chemical industry's fortunes. And they are the most vulnerable to economic cycles. For instance, executives within the chemical industry and especially at very small companies say their plants may still be sold out, but these are mainly in very small volume niche products. The big chemical plants, producing large-volume organic and inorganic chemicals, are having problems. And these problems may be on the rise, stimulated by a number of factors.

Chemical operations at oil companies provide an insight into problems in the petrochemical industry. For eight oil companies—Amoco, Chevron, Exxon, Mobil, Occidental, Shell, Texaco, and Unocal—earnings from chemical operations declined 47% in the second quarter to a total of $1.30 billion. And the declines at the individual companies were not modest—ranging from 24% at Unocal to 66% at Texaco. Almost all of the oil companies point to lower prices, especially for olefins and aromatics, and higher feedstock costs.

The same dominance of commodity chemicals can be seen at narrowly drawn chemical companies such as Quantum, where earnings were down 85%; Vista, down 42%; and Georgia Gulf, off 37%. All three of these companies rely heavily on one type of product. At Vista it is polyvinyl chloride; Georgia Gulf, chlor-alkalis; and Quantum, polyolefins.

Capacity utilization in the chemical industry has been trending downward over the past few months, held up in part, it seems, by exports. According to government data, capacity utilization for chemicals and products was a preliminary 81.8% in June, down from 82.6% in January, but this includes noncyclical products such as pharmaceuticals. Absent these categories, the use rate is probably falling faster.

For instance, Dow says its capacity use rate was 89% in the second quarter, and, while still high, was down from 92% in the first three-month period this year.

The industry has been trying to export to maintain capacity use levels, and this may be working in terms of volume. But export prices of chemicals have been falling, often resulting in lowered profitability from those products sent overseas. In the first five months of this year, the value of exports of chemicals and allied products was up about 5% from the levels of the same period in 1989. But some of the large-volume categories are down from the levels of a year ago. For instance, fertilizer exports fell almost 3% in the latest five-month period when compared with January through May a year earlier, and exports of inorganic and organic chemicals dropped more than 10%. Of the large-volume categories, only plastics improved, according to government data, but rose less than 1% for the January through May period. Du Pont says U.S. volume decreased 5%, while volume in other regions increased 6% from the year-ago quarter. And, it says, the increase in volume outside the U.S. came almost entirely in Europe.

For the remainder of the year, companies remain fairly optimistic in the projections that accompanied their earnings announcements. At Union Carbide, chairman Robert D. Kennedy said he is pleased with results at this point in the business cycle. According to Kennedy, the results reflect the strong focus of the company in its leading businesses. And he said he is encouraged by still strong chemical volumes and particularly pleased by the strong performance of the company's industrial gas business.

Richard J. Mahoney, Monsanto's chairman, said, "While Monsanto's overall second-quarter financial performance wasn't as strong as we hoped earlier in the year, our businesses remain fundamentally very solid and on track when measured against Monsanto's short- and long-term financial objectives."

Enrique C. Falla, Dow's financial vice president, says, "Even with the weakening economic and industry

Earnings fell at oil companies, but were up at diversified and pharmaceutical manufacturers

	SECOND-QUARTER 1990						FIRST-HALF 1990					
	Sales	Earnings[a]	Change from 1989		Profit margin[b]		Sales	Earnings[a]	Change from 1989		Profit margin[b]	
	($ millions)		Sales	Earnings	1990	1989	($ millions)		Sales	Earnings	1990	1989
OIL AND GAS COMPANIES												
American Petrofina	$ 832.6	$ 53.8	−2%	29%	6.5%	4.9%	$ 1,728.9	$ 80.0	10%	18%	4.6%	4.3%
Amoco	7,450.0	379.0	9	−24	5.1	7.3	14,521.0	845.0	9	−12	5.8	7.2
Chevron	8,900.00	590.0	9	15	6.6	6.3	18,300.00	1057.0	15	45	5.8	4.6
Exxon	26,088.0	1100.0	10	11	4.2	4.2	52,801.0	2,380.0	15	4	4.5	5.0
Kerr-McGee	845.8	30.1	3	−13	3.6	4.2	1,657.6	57.2	8	−17	3.5	4.5
Mobil	13,820.0	428.0	−2	−21	3.1	3.9	28,853.0	856.0	3	−12	3.0	3.5
Occidental Petroleum	5,122.0	69.0	1	−18	1.3	1.7	10,281.0	179.0	1	12	1.7	1.6
Phillips Petroleum	2,859.0	105.0	−12	−47	3.7	6.0	5,975.0	364.0	−5	−6	6.1	6.1
Shell Oil	5,174.0	161.0	−12	−63	3.1	7.5	10,928.0	363.0	−1	−55	3.3	7.3
Sun Co.	2,890.0	115.0	−1	64	4.0	2.4	6,000.0	186.0	8	23	3.1	2.7
Texaco	8,721.0	353.0	3	−4	4.0	4.3	17,877.0	681.0	−1	8	3.8	3.5
Unocal	2,716.0	33.0	−11	−65	1.2	3.1	5,359.0	110.0	−6	−40	2.1	3.2
TOTAL	**$85,418.4**	**$3416.9**	**3%**	**−12%**	**4.0%**	**4.7%**	**$174,281.5**	**$ 7158.2**	**7%**	**−3%**	**4.1%**	**4.5%**
DIVERSIFIED MANUFACTURERS												
Allied-Signal	$ 3,184.0	$ 121.0	2%	−15%	3.8%	4.6%	$ 6,239.0	$ 250.0	3%	−7%	4.0%	4.4%
Du Pont	9,646.0	694.0	4	−3	7.2	7.7	19,050.0	1,309.0	6	−10	6.9	8.1
Eastman Kodak	4,872.0	384.0	2	26	7.9	6.4	8,983.0	583.0	0	13	6.5	5.7
Engelhard	751.3	18.2	25	20	2.4	2.5	1,409.8	39.9	18	35	2.8	2.5
FMC	987.2	54.8	8	−1	5.6	6.1	1,800.7	92.8	3	4	5.2	5.1
Ferro Corp.	282.1	7.1	2	−46	2.5	4.8	561.8	13.1	3	−49	2.3	4.7
3M	3,234.0	342.0	7	5	10.6	10.8	6,398.0	677.0	6	5	10.6	10.7
NL Industries	230.6	40.8	−14	−1	17.7	15.3	400.8	65.5	0	−22	16.3	20.9
PPG Industries	1,571.6	166.0	5	30	10.6	8.5	3,049.9	291.3	3	13	9.6	8.7
Tenneco	3,636.0	206.0	−1	14	5.7	4.9	7,238.0	340.0	4	18	4.7	4.1
Vulcan Materials	295.7	39.7	1	−9	13.4	14.8	527.7	58.3	3	−2	11.1	11.6
TOTAL	**$28,690.4**	**$2073.6**	**4%**	**6%**	**7.2%**	**7.1%**	**$ 55,658.7**	**$ 3720.0**	**4%**	**0%**	**6.7%**	**7.0%**
PHARMACEUTICAL COMPANIES												
Abbott Laboratories	$ 1,503.4	$ 240.2	14%	13%	16.0%	16.1%	$ 2,941.8	$ 465.2	13%	13%	15.8%	15.7%
American Home Products	1,605.1	270.4	1	13	16.8	15.1	3,418.5	584.8	3	13	17.1	15.6
Baxter International	2,003.0	110.0	8	6	5.5	5.6	3,906.0	−273.0[c]	8	def	def	5.6
Bristol Myers-Squibb	2,483.9	417.3	11	21	16.8	15.4	4,941.6	826.3	10	20	16.7	15.3
Merck	1,899.3	470.2	20	19	24.8	25.0	3,657.8	874.0	16	19	23.9	23.3
Pfizer	1,495.0	151.2	15	11	10.1	10.4	2,977.7	403.1	9	7	13.5	13.7
Schering-Plough	864.0	144.1	7	20	16.7	15.0	1,729.1	294.5	6	20	17.0	15.0
Upjohn	804.7	114.1	11	21	14.2	13.0	1,577.6	228.3	7	15	14.5	13.5
Warner Lambert	1,154.8	134.5	13	20	11.6	11.0	2,254.8	254.8	10	19	11.3	10.4
TOTAL	**$13,813.1**	**$2051.9**	**11%**	**17%**	**14.9%**	**14.1%**	**$ 27,404.9**	**$ 3658.1**	**9%**	**2%**	**13.3%**	**14.3%**

[a] After-tax earnings from continuing operations, excluding significant extraordinary and nonrecurring items. [b] After-tax earnings as a percentage of sales. [c] Includes $566 million pretax restructuring charge. def = deficit.

conditions, we anticipate that 1990 will be Dow's best year in sales and third best in profitability. Assuming a gradually improving global economy and stable margins in the ethylene chain, Dow is positioned for improved earnings in 1991."

However, these projections came out a few weeks ago and things have changed since then; now it is the "gradually improving global economy" that is in question. As of several weeks ago, it looked as if the industry might limp along through the rest of 1990 with a gradually slackening demand leading to lower prices and declining margins. At press time, however, the world situation was volatile enough to call even this mildly pessimistic outlook into question. □

AUGUST 20, 1990
CHEMICAL & ENGINEERING
NEWS

Facts & Figures for Chemical R&D

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CHEMICAL & ENGINEERING NEWS

AUGUST 20, 1990

News of the Week

- **Department of Justice for the first time has joined in fraud suit alleging scientific misconduct against an Adams State University immunologist and two of the universities at which he did research.** Page 6
- **House committee issues report charging government engaged in plot to deny responsibility for agent orange exposure by troops that served in Vietnam.** Page 7
- **Attorneys for ACS and Dialog clash over several issues in antitrust suit involving Chemical Abstracts Service.** Page 7
- **Argonne National Laboratory researchers devise new method for producing high-purity yttrium-90 from strontium-90.** Page 8

Business

Sales and earnings fell for most Canadian chemical companies during this year's first six months, reflecting the weakness that has begun to pervade the Canadian economy. **Page 15**

Indonesia has initiated a huge petrochemical expansion program in an effort to cut imports of basic chemicals and their derivatives. **Page 16**

Chemical earnings of both BP and Shell have been hit hard by rising oil prices. **Page 17**

Government

Changes in the immigration law to head off the looming shortfall of U.S. scientists were probed in recently held House hearings. **Page 19**

Cooperative effort working toward zero-accident process safety is urged in an American Institute of Chemical Engineers report. **Page 20**

Proposed taxes on U.S. fossil fuels consumption is drawing fire from the chemical industry. **Page 20**

Science/Technology

New Beckman Institute for Advanced Science & Technology aims at promoting wide-ranging research across a number of disciplines. **Page 23**

Books

Two new books on the greenhouse effect present prevention as solution to industrially driven ills, ask if people can muster political will. **Page 63**

Cover: Researchers at Research Triangle Institute use vapor-phase deposition to develop materials for cascade solar cell design

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Special Report

C&EN's annual look at chemical R&D statistics indicates an overall sluggish growth rate with total U.S. spending projected to reach $150 billion in 1990—a mere 1% increase after adjusting for inflation. **Page 28**

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LETTERS

CHEMICAL SAFETY

Decomposition of benzyl fluoride

A 25-g bottle of commercial benzyl fluoride (CAS Registry Handbook No. 350-50-5) decomposed spontaneously in our laboratory recently. Glass fragments from the bottle and from five other adjacent bottles were scattered within the storage cabinet. The fragments were coated with an off-white resin and the odor in the cabinet was acrid. No one was injured.

The sample had been purchased more than a year ago and was kept in storage at room temperature after a 2-g portion was used. The label contained no warning about potential hazards due to instability. A material safety data sheet indicated that the compound was stable and that "hazardous polymerization will not occur."

C. K. Ingold and E. H. Ingold [*J. Chem. Soc.*, 2249 (1928)] reported the initial preparation of benzyl fluoride and described its spontaneous decomposition in glass vessels. They suggest that an autocatalytic polymerization commences at the glass surface and proceeds with the evolution of hydrogen fluoride, in some cases with almost explosive violence. Stability during distillation and storage was reported to depend on the type of glass used.

Six commercial suppliers of benzyl fluoride are listed in the 1990 edition of "Chem Sources—U.S.A.," and two are listed in the 1988 edition of "Chem Sources—International." One former supplier has notified us that it decided to discontinue supplying it as a result of two incidents involving its violent decomposition in glass bottles.

I urge that current suppliers reevaluate the potential hazard associated with the instability of benzyl fluoride in glass bottles. I strongly recommend that benzyl fluoride be used and stored in nonglass apparatus unless the glass is known to be nonreactive.

Stephen S. Szucs
Agricultural Research Division
American Cyanamid Co.
Princeton, N.J.

CAS nomenclature

What is the Chemical Abstracts Service name for 1,2-dichlorotetraphenylethane? This simple and beautifully symmetrical compound, whose name is so descriptive that a sophomore after two weeks of Organic I can go easily from the name to the structure or vice versa, has the following CAS name: benzene,1,1′,1″,1‴-(1,2-dichloro-1,2-ethanediylidene)tetrakis.

Like so many other chemists, I have occasionally pondered similar cases of CAS lexicopathy and wondered at the cause of the condition. My reluctant conclusion was that this is an unanswerable problem, tied up as it is with the perversity of human nature and perhaps the perversity of the universe itself. Why does a piece of buttered bread always land on the floor face downward?

Recently, when I had the occasion to use CAS Online to search the literature for references to the above dichloride, I saw the glimmer of an answer to the above mystery. You can get all the literature references for the period between 1968 and the present for the above compound on the CA File for about $10—a fairly reasonable price. To do this search however, you need to know the CA Index name or the Registry Number. To get this you access the Registry File and draw the structure of the compound. This costs $40. By using a gobbledygook name, CAS increased its income fivefold!

Can this be the answer to the mystery of CA nomenclature? Probably not. Truly profound questions like these must have answers that go deeper than this. Perhaps the answer is to switch from buttered bread to bread and butter sandwiches.

Paul Haberfield
Professor of Chemistry
Brooklyn College
The City University of New York

CAS replies: Chemical Abstracts Service made a major revision in the assignment of chemical substance index names in 1972 with the switch to more fully systematic names and the elimination of most trivial names. This was done so

Sales and Earnings Decline for Most Canadian Chemical Companies

Weak domestic economy, both in manufacturing and markets, and an overvalued Canadian dollar have combined to hurt Canadian chemical business

Weakness has started to pervade the Canadian economy. And, along with most of their manufacturing counterparts, Canadian chemical companies are starting to reflect this weakness on their bottom lines.

Many industry leaders agree with J. E. (Ted) Newall, chairman and chief executive officer of Du Pont Canada, that Canada's manufacturing sector and most of its domestic markets will remain weak for the rest of the year. That's bad news for Canada's chemical companies. The good news: The economic situation probably won't get as bleak as it was during the 1981–82 recession.

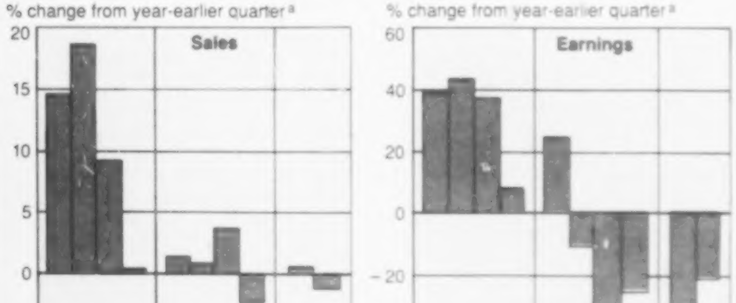
As a result, earnings of all four of the major, publicly traded Canadian chemical companies declined during the first six months of the year, compared with the first half of 1989. Some of the drops were sharp, such as the 65% decline in Union Carbide Canada's earnings and the 56% dip in Nova Corp.'s operating income from its petrochemical, plastics, and rubber businesses.

Softness in commodity petrochemical markets contributed to both Union Carbide Canada's and Nova's problems. While Carbide Canada's sales were down only 5.9% to $211 million during the first half, net income plummeted 65% to $6.9 million. Chairman W. Norman Kissick attributes the lower sales to lower petrochemical volumes and prices.

The hit on earnings, he says, reflects the impact of the petrochemical down cycle on the earnings of Pétromont, the Montreal-based petrochemical producer that Carbide owns equally with Le Groupe SGF.

For Celanese Canada, the situation was reversed. Sales for the first half of 1990 were down 5.9% to $162 million. But net income declined only 0.8% to $21.6 million. Rare among Canadian chemical companies, Celanese Canada's earnings actually increased during the second quarter this year, even though sales slipped more than 2%.

Earnings dropped more than sales



Note: Combined results of Celanese Canada, Du Pont Canada, and Union Carbide Canada. a Based on Canadian currency.

Gerald P. Elden, president of Celanese Canada, attributes part of this to polyester staple. While weak markets for the staple forced sales volumes down, lower raw material costs helped to maintain income levels. In contrast, both domestic and export markets for heavy industrial yarn were strong and the unit remained sold out.

Performance varied throughout the company. The cellulosic division's sales and earnings were down because of the higher value of the Canadian dollar, relative to other currencies, which hurt exports. Industrial product sales and earnings were up, buoyed by strong markets for cigarette filter tow. And weak methanol prices put the damper on chemical sales and earnings.

Du Pont Canada's earnings were down 25% during the first half, despite an almost 3% boost in sales. Newall says that many of the company's businesses boosted sales volumes. However, this was not enough to offset lower prices, particularly for polyethylene resins. One ray of hope: The polyethylene resin business improved in the second quarter, compared with the first quarter, and Newall expects this trend to continue for the remainder of the year.

Newall notes that the economic slowdown became more apparent in the second quarter. Domestic demand for many of Du Pont Canada's products declined. For the first half, domestic sales were off 7%, but export sales, particularly to the U.S., were up more than 40%. The free trade agreement with the U.S., says Newall, already is providing his

Canadian chemical companies head for poor year

$ Millions[a]	Net sales	Change from 1989[b]	Net income[c]	Change from 1989[b]	Profit margin[d] 1990	Profit margin[d] 1989
			SECOND-QUARTER 1990			
Celanese Canada	$ 84.2	−2.3%	$ 10.8	4.1%	12.8%	12.0%
Du Pont Canada	349.8	1.1	22.5	−12.6	6.4	7.4
Nova Corp.[e]	743.6	0.1	82.1	−46.1	na	na
Union Carbide Canada	104.6	−7.8	0.8	−89.4	0.7	6.4
			FIRST-HALF 1990			
Celanese Canada	$ 161.9	−5.9%	$ 21.6	−0.8%	13.3%	12.7%
Du Pont Canada	653.8	2.9	40.1	−25.3	6.1	8.5
Nova Corp[e]	1469.0	−3.7	156.4	−56.3	na	na
Union Carbide Canada	211.1	−5.9	6.9	−65.4	3.3	8.9

a $1.00 = $1.170 Canadian (second quarter) and $1.176 Canadian (first half). b Based on Canadian currency. c Based on continuous operations and excluding extraordinary items. d Net income as percentage of sales. e Includes petrochemical, plastics, and rubber operations only. Nova does not break out net income by division. Income shown is operating income, which does not compare with net income of other companies. na = not applicable.

company with new business opportunities.

How strong those opportunities will be over the short term remains to be seen. Newall concedes that near-term prospects depend on demand in the U.S. But there are signs that some of Du Pont Canada's important U.S. markets are softening.

Meanwhile, high interest rates and an overvalued Canadian dollar are hurting Du Pont Canada's domestic customers. As a result, Newall calls the outlook for the rest of the year "uncertain." But, he says, "We expect a weaker last half."

Most leaders in the Canadian chemical industry agree with him. Carbide Canada's Kissick, for instance, sees no improvement in petrochemical profits for the balance of the year. And Celanese Canada's Elden says he doesn't expect this year's earnings to equal those of 1989.

Earl Anderson

Indonesia launches petrochemicals expansion

In an effort to reduce imports of basic chemicals and their derivatives, Indonesia has embarked on an ambitious petrochemical expansion binge. The country expects that more than $6 billion will be invested in its basic chemical industry over the next five years.

This new investment likely will support a 13% annual growth rate for Indonesia's chemical industry over that time span and provide more than 35,000 new jobs. It also may triple the value of Indonesia's chemical exports. The problem is that other Asian nations have their own petrochemical expansion plans in the works. As a result, the danger of overcapacity in the region is a very real one.

Most of the $6 billion is earmarked for Indonesia's petrochemical industry. However, some of it will go into fine and specialty chemicals and to boost the country's ability to process its cellulose resources, agricultural products, and waste.

Many of Indonesia's petroleum-derived downstream industries, such as polyvinyl chloride pipe and synthetic fibers, are already well developed. The country already has 56 chemical plants that produce about $4 billion worth of chemicals per year. Chemical exports run well over $550 million annually.

Indonesia's basic petrochemical industry, however, has lagged behind. The country produces enough urea, ammonia, and methanol, but still relies heavily on imports for most other petrochemicals. For instance, it imports most of the high-volume, general-purpose resins, including both high- and low-density polyethylene, polypropylene, polystyrene, and polyvinyl chloride. However, with its new petrochemical investment, Indonesia expects to become self-sufficient in petrochemicals within five years.

The plants scheduled to be built in Indonesia run the gamut of the petrochemical spectrum. Shell, C. Itoh, and Mitsubishi, for instance, are part of a Dutch-Japanese-Indonesian consortium that will build an olefins complex at Cilacap in Central Java. When it comes on stream in 1994, the $1.5 billion complex will produce polyethylene, polypropylene, monoethylene glycol, diethylene glycol, and butadiene.

Dow Chemical will be a joint-venture partner in a $20 million plant that is scheduled to be on stream next year in Merak, West Java. The unit will produce 20,000 metric tons per year of general-purpose and high-impact polystyrene. It will get its raw material from a styrene plant that also is being built in Merak.

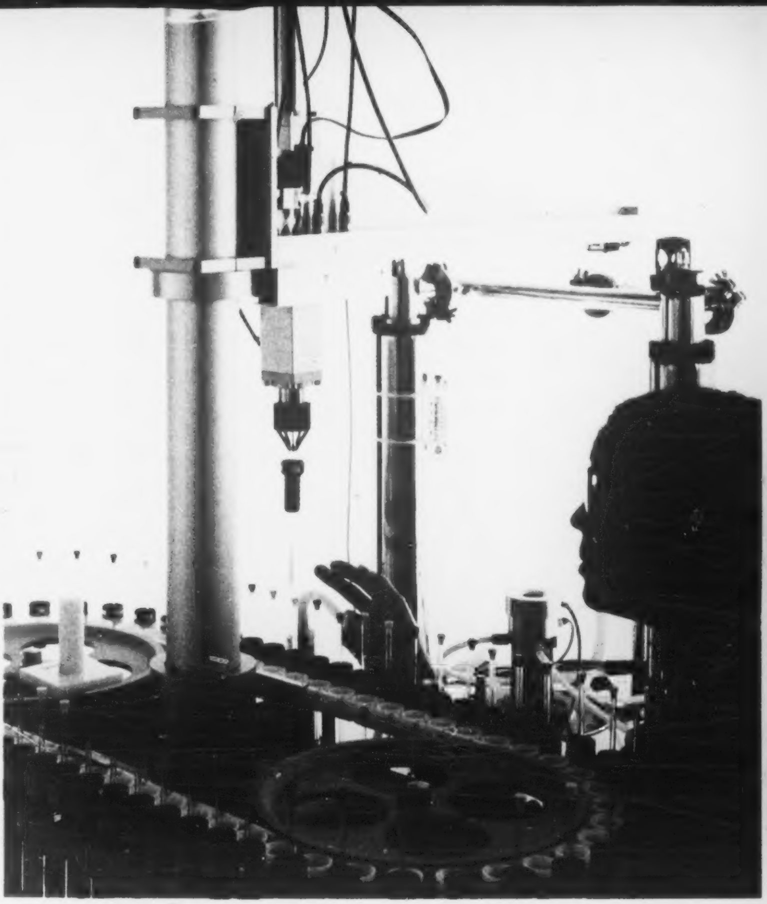
PPG Industries is leading a U.S.-Japanese-Indonesian venture that will produce caustic soda and chlorine, vinyl chloride, polyvinyl chloride, and other chlorinated chemicals in West Java. The $200 million venture already is on stream.

P. T. Arsento, a company of the Royal Dutch Shell group, is chipping in with a 300,000 metric-ton-per-year, $300 million polyethylene plant in Musi, West Java. And a consortium of four companies is building a polypropylene unit in Tangerang, also in West Java, that is due on stream late this year. Output will be used primarily for plastic bags and consumer goods.

Multinational joint ventures also are leading a surge in new aromatics capacity. One unit, on Sumatra, will produce 3.1 million metric tons of aromatics annually, all of it earmarked for the export market. And another $1.3 billion aromatics complex in Arun, North Sumatra, will produce benzene, toluene, mixed-xylenes, *o*-xylene, cyclohexane, and other aromatics intermediates.

Purified terephthalic acid and *p*-xylene plants also have been completed or are on the drawing boards for Indonesia. But the ever-present fear of overcapacity in Asia could compel Indonesia to reconsider some of its ambitious petrochemical projects.

Earl Anderson



Facts & Figures for Chemical R&D

Bette Hileman, C&EN Washington

The rate of growth in overall R&D funding this year has been sluggish. According to estimates made by the National Science Foundation, spending on R&D in the U.S. could reach $150 billion in 1990. That would be a 6% increase from funding in 1989—but only a 1% increase after adjusting for inflation.

Of the three major contributors to R&D—the federal government, industry, and universities—only universities are hiking R&D monies substantially in 1990: 7% after an adjustment for inflation. In real terms, industry funding at $74 billion and federal government funding at $69 billion are only 1% higher than the 1989 figures.

In the mid-1980s, total R&D spending was rising at 9 or 10% per year in constant dollars. But in the late 1980s, growth slowed to an annual rate of 3%, and in 1989 and 1990, it has almost come to a halt. Another way to look at it is that real R&D spending grew 40% between 1980 and 1985. Since then, the real gain has been only 11%.

The recent slowdown reflects, in part, sluggish growth in defense-related R&D. In 1977, only 23% of the total R&D funds were spent on defense. This share rose to 30% during the middle of the Reagan Administration and has held steady at 28% since 1987.

The share of the gross national product claimed by R&D in the U.S. has followed a similar pattern. It rose from a 20-year low of 2.1% in 1978 to 2.8% in 1985 and 1986, then fell to the current slightly lower figure of 2.7%. The share of GNP accounted for by nondefense R&D has remained steady at from 1.9 to 2.0% since 1983; its level is 1.9% this year.

Vast differences can be seen among the R&D efforts of different countries in terms of GNP used for R&D. Five countries—Sweden, Israel, Japan, Switzerland, and West Germany—spend a greater share of their GNP on R&D than the U.S. Hungary, France, the U.K., and the Netherlands spend from 2.2 to 2.6%, and a number of other countries with high-technology economies, such as South Korea, Norway, Italy, and Austria, spend only between 1.0 and 1.8%. Third World countries devote even smaller shares of their GNP to R&D.

Nevertheless, overall spending for R&D in the U.S. still dwarfs that of any other nation. In 1988, U.S. R&D funding was 2.6 times larger than Japan's, the next highest spender, and 5.7 times that in West Germany.

Even greater differences among countries can be seen when funds for defense R&D are considered. In 1988, Japan used only 1% of its total R&D funds for defense and West Germany used 2% for this purpose. The U.K. (24%) and France (23%) also spent smaller shares of their total R&D funds on defense than the U.S. In fact, the portion the U.S. used for defense (28%) was greater than that of any other nation for which data are available.

When the U.S. and Japan are compared on the basis of R&D performance, the U.S. comes out second

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How R&D efforts in the U.S. compare with those in other nations, particularly Japan and the countries of Western Europe 55

best in many areas. For example, Japan's share of chemical literature abstracted by Chemical Abstracts Service has climbed steadily from 7.5% in 1973 to 11.8% in 1989, whereas the U.S.'s share crept up from 26.4% to 27.8%. In Japan, the number of R&D scientists and engineers has grown rapidly as a fraction of the total work force to 68.8 per 10,000 in 1987. In the U.S. their proportion is also rising, but more slowly. An indication of this is that in 1988 alone, the actual number of scientists and engineers in Japan increased 11%, whereas it grew only 3% in the U.S. In the U.S., however, the fraction of the work force employed in science and engineering—75.9 per 10,000—is still greater than it is in Japan or in any other country that NSF collects data for.

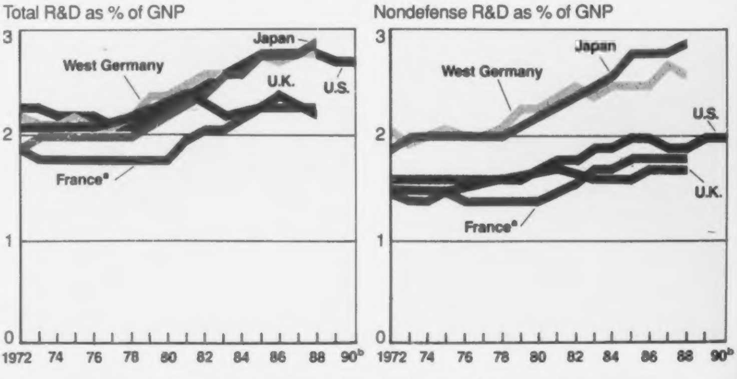
Japan's progress vis-à-vis the U.S. can be seen even more clearly in the number of chemical patents granted by the U.S. Patent & Trademark Office. The U.S. share of chemical patents granted to all recipients declined from 57% in 1980 to 51% in 1989; at the same time the portion granted to Japanese citizens, corporations, and government agencies rose from 12% to 20%. The shares of patents awarded to West Germany, the U.K., France, Switzerland, and Canada have remained fairly steady since 1980.

Another indication suggesting a decline in U.S. science and engineering relative to other countries is that the percent of foreign graduate students in all fields of science and engineering in the U.S. rose from 26% in 1983 to 32% in 1988. In chemistry, foreign graduate students represent 33% of the total.

Even more disturbing for the future of U.S. chemical R&D is the recent drop in the total number of graduate students in chemistry and chemical engineering (both foreign and U.S. students), which fell in 1988 for the first time in more than a decade. The number of B.S. and M.S. degrees granted in chemistry and chemical engineering also has fallen precipitously. Only the number of Ph.D. degrees increased, but that trend, too, probably will reverse itself in a few years because the graduate student population is declining.

The decrease in the number of graduate students in chemistry and chemical engineering is consistent with another, broader trend in the U.S. The total number of bachelor's degrees granted in science and engineering fell 9% between 1986 and 1988. For women science students, the decline was the first ever. So far,

R&D share of GNP similar in U.S., Japan, West Germany, but if defense excluded U.S. lags the other two



Note: 1989 percentages are C&EN estimates. **a** French data are based on gross domestic product, consequently percentages may be slightly overstated. **b** C&EN estimates. **Source:** National Science Foundation the decline in the number of science and engineering students has not had any obvious effect on university funding for R&D, which has grown strongly in recent years.

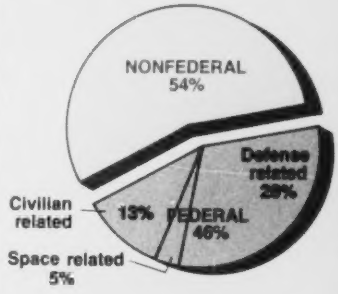
Of the $150 billion total funding for R&D in the U.S. in 1990, $21.5 billion (14%) will be spent on basic research, $33.8 billion (23%) on applied research, and $94.7 billion (63%) on development. During the past decade, funding for basic research has risen at an annual rate of about 10%, and that for applied research and development has increased about 9% annually.

According to NSF estimates, the federal government provided $777 million for research in chemistry in the fiscal year that ended September 1989 (this excludes development)—a gain of 11% from the previous year. Most of the funds were contributed by four agencies: the departments of Energy, Defense, and Health & Human Services, and by NSF. Similarly, federal funds for chemical engineering research rose 12% to $290 million in 1989. The Energy Department continues to supply the largest amount of funds ($146 million) to chemical engineering research, and the Defense Department and NSF tie for second place, with about $40 million to $50 million each. Funds supplied by the federal government for chemistry and chemical engineering research, however, are only about 5% of the total government funding for all science and engineering research.

Universities also spent about 5% of their total science and engineering R&D outlays on chemistry and chemical engineering. More than half of these funds (in chemistry, 71%) are supplied by the federal government. In all, universities themselves and other nonfederal sources provided only $238 million for R&D in chemistry and chemical engineering at universities.

The chemical industry itself is the largest supporter of chemistry and chemical engineering research. The total funds for all industrial R&D edged above $100 billion last year, an increase of 4% over 1988, and of this, about 12%, or $11.9 billion (up 10%), was spent by the chemicals and allied products industry. Drug companies increased their R&D spending 14% to $5.4 billion in 1989 and helped boost the overall spending by all producers of chemicals and allied products.

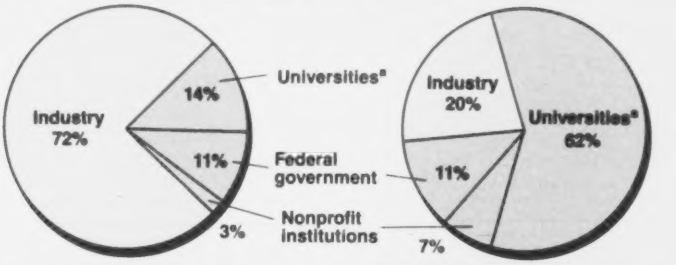
Defense takes more than a quarter of U.S. R&D funds



Estimated 1990 total R&D spending = $150 billion

Source: National Science Foundation

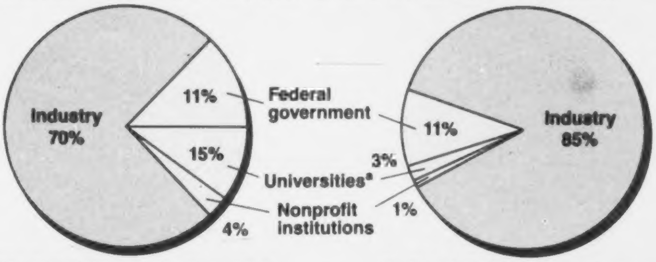
Only about a fourth of total R&D goes on in nonindustrial labs, even though they do 80% of basic research...



Estimated 1990 total R&D spending = $150 billion

Estimated 1990 basic research spending = $21 billion

...because industry performs 70% of applied research and accounts for an even bigger share of all development



Estimated 1990 applied research spending = $34 billion

Estimated 1989 development spending = $95 billion

[a] Includes associated federally funded R&D centers. Source: National Science Foundation

Because about 70% of the R&D funds spent by the chemicals and allied products industry and about 3% of R&D funds spent by other industries goes for R&D in various aspects of chemical science and technology, industry probably spends about $10.9 billion in this area. When that is added to the $1.1 billion contributed by the federal government and the $200 million contributed by universities, the approximate total spent on R&D in chemistry and chemical engineering in the U.S. was about $12.2 billion in 1989. This was about 8% of the money that went into R&D in all fields of science and engineering.

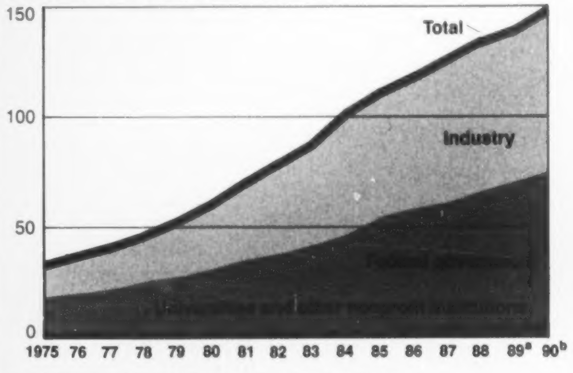
Information for this Special Report is collected primarily from NSF's Division of Science Resources Studies, which publishes detailed statistical studies of most of the areas the report covers. These studies are available from the National Science Foundation, Division of Science Resources Studies, Office of the Director, 1800 G St., N.W., Washington, D.C. 20402, phone (202) 634-4634. □

1 R&D Overview

R&D Outlays Move Up to $150 Billion

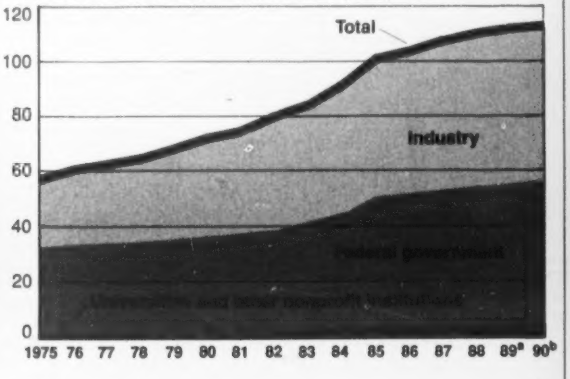
In current dollars, R&D spending rose more than 10% since 1988 . . .

Sources of R&D funds, $ billions, current



. . . but in real terms, it began to level off in the late 1980s

Sources of R&D funds, $ billions, constant (1982)



a Preliminary. b Estimated. **Source:** National Science Foundation

SOURCES OF R&D FUNDS: **Almost all come from industry and government**

$ Billions, current	1990[a]	1989[b]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Industry	$ 74.3	$ 70.4	$ 67.9	$ 64.1	$ 61.1	$ 58.0	$ 52.2	$ 45.3	$ 40.7	$ 35.9	$ 30.9	$ 26.1	$ 22.5	6%	12%
Federal government	69.2	65.9	62.1	58.5	54.6	52.1	45.6	40.8	36.6	33.4	29.5	26.8	23.9	6	10
Universities and colleges	4.3	3.9	3.4	3.1	2.8	2.4	2.1	1.9	1.7	1.5	1.3	1.2	1.0	10	13
Other nonprofit institutions	2.3	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.0	1.0	0.9	0.8	0.8	14	9
TOTAL	**$150.0**	**$142.0**	**$135.2**	**$127.3**	**$119.9**	**$113.7**	**$101.1**	**$ 89.1**	**$ 80.0**	**$ 71.9**	**$ 62.6**	**$ 54.9**	**$ 48.1**	**6%**	**11%**
ANNUAL CHANGE	**6%**	**5%**	**6%**	**6%**	**5%**	**12%**	**13%**	**11%**	**11%**	**15%**	**14%**	**14%**	**12%**		
$ Billions, constant 1982															
Industry	$ 56.4	$ 55.7	$ 55.9	$ 54.6	$ 53.7	$ 52.3	$ 48.5	$ 43.6	$ 40.7	$ 38.2	$ 36.1	$ 33.2	$ 31.1	2%	6%
Federal government	52.6	52.1	51.2	49.8	48.0	47.0	42.4	39.3	36.6	35.5	34.4	34.1	33.1	3	4
Universities and colleges	3.3	3.0	2.8	2.7	2.4	2.1	1.9	1.8	1.7	1.6	1.5	1.5	1.4	6	7
Other nonprofit institutions	1.7	1.5	1.5	1.4	1.2	1.2	1.1	1.1	1.0	1.0	1.1	1.1	1.1	-10	3
TOTAL	**$114.0**	**$112.4**	**$111.5**	**$108.4**	**$105.3**	**$102.6**	**$ 93.9**	**$ 85.8**	**$ 80.0**	**$ 76.4**	**$ 73.0**	**$ 69.9**	**$ 66.7**	**3%**	**5%**
ANNUAL CHANGE	**1%**	**1%**	**3%**	**3%**	**3%**	**9%**	**9%**	**7%**	**5%**	**5%**	**5%**	**5%**	**5%**		

Note: Constant-dollar values are calculated by C&EN based on NSF data. a NSF estimates. b Preliminary figures. **Source:** National Science Foundation

PERFORMERS OF R&D: Share done by academia has been increasing most rapidly recently

$ Billions, current	1990^a	1989^b	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Industry	$108.2	$103.0	$ 99.4	$ 94.1	$ 88.2	$ 84.2	$ 74.8	$65.3	$58.7	$51.8	$44.5	$38.2	$33.3	6%	12%
Federal government	16.7	15.8	14.3	13.4	13.5	12.9	11.6	10.6	9.1	8.4	7.6	7.4	6.8	6	8
Universities and colleges	15.8	14.5	13.4	12.1	10.9	9.7	8.6	7.9	7.3	6.8	6.0	5.4	4.6	11	11
University-associated FFRDCs^c	5.2	4.9	4.5	4.2	3.9	3.5	3.2	2.7	2.5	2.5	2.2	1.9	1.7	7	10
Other nonprofit institutions	4.1	3.9	3.6	3.5	3.4	3.4	3.0	2.7	2.4	2.3	2.2	2.0	1.7	2	8
TOTAL	**$150.0**	**$142.0**	**$135.2**	**$127.3**	**$119.9**	**$113.7**	**$101.1**	**$89.1**	**$80.0**	**$71.9**	**$62.6**	**$54.9**	**$48.1**	**6%**	**11%**
$ Billions, constant 1982															
Industry	$ 82.2	$ 81.6	$ 82.0	$ 80.2	$ 77.5	$ 75.9	$ 69.5	$62.8	$58.7	$55.1	$51.9	$48.6	$46.1	2%	6%
Federal government	12.7	12.5	11.8	11.4	11.9	11.7	10.7	10.2	9.1	9.0	8.9	9.4	9.4	3	2
Universities and colleges	12.0	11.4	11.1	10.3	9.6	8.7	8.0	7.6	7.3	7.3	7.1	6.8	6.4	8	6
University-associated FFRDCs^c	4.0	3.8	3.7	3.6	3.4	3.2	2.9	2.6	2.5	2.6	2.6	2.5	2.4	4	5
Other nonprofit institutions	3.1	3.1	2.9	3.0	2.9	3.0	2.8	2.6	2.4	2.4	2.5	2.5	2.3	−1	2
TOTAL	**$114.0**	**$112.4**	**$111.5**	**$108.4**	**$105.4**	**$102.5**	**$ 93.9**	**$85.8**	**$80.0**	**$76.5**	**$73.0**	**$69.9**	**$66.7**	**3%**	**5%**

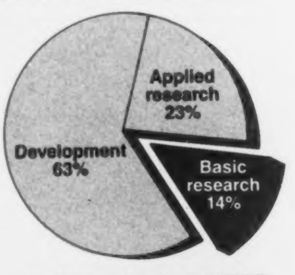
Note: Constant-dollar values are calculated by C&EN based on NSF data. a Estimated. b Preliminary. c Federally funded R&D centers. **Source:** National Science Foundation

U.S. CHEMICAL PATENTS: Total jumped by nearly a quarter last year

Number of patents issued	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	Total 1980–89
U.S. origin	**13,863**	**11,342**	**11,485**	**10,627**	**11,607**	**11,566**	**10,652**	**10,667**	**12,790**	**11,347**	**115,946**
to U.S. corporations	12,069	9,891	9,934	9,266	10,224	10,154	9,211	9,208	11,041	9,754	100,752
to U.S. government	327	300	366	326	322	378	331	312	367	366	3,395
to individuals in the U.S.	1,308	1,025	1,056	936	1,009	958	1,013	1,045	1,306	1,149	10,805
to foreign-owned corporations in the U.S.	159	126	129	99	52	76	97	102	76	78	994
Foreign origin	**13,172**	**10,575**	**10,284**	**9,135**	**9,717**	**9,030**	**8,110**	**8,038**	**9,660**	**8,387**	**96,108**
to U.S.-owned corporations abroad	1,131	854	854	760	885	839	705	733	904	823	8,488
to foreign corporations	11,139	8,963	8,673	7,698	8,104	7,463	6,746	6,532	7,882	6,790	79,990
to foreign governments	175	173	200	148	161	166	134	165	100	96	1,518
to foreign individuals	727	585	557	529	567	562	525	608	774	678	6,112
TOTAL	**27,035**	**21,917**	**21,769**	**19,762**	**21,324**	**20,596**	**18,762**	**18,705**	**22,450**	**19,734**	**212,054**
% FOREIGN	**48.7%**	**48.3%**	**47.2%**	**46.2%**	**45.6%**	**43.8%**	**43.2%**	**43.0%**	**43.0%**	**42.5%**	**45.3%**

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. **Source:** U.S. Patent & Trademark Office

Basic research gets only a seventh of R&D funds



Estimated total 1990 R&D spending = $150 billion

Source: National Science Foundation

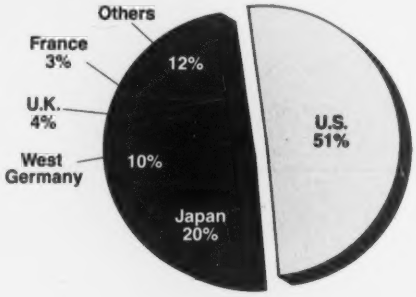
RECIPIENTS OF U.S. CHEMICAL PATENTS: U.S.'s share continues steady decline

% of patents	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	Total 1980–89
U.S. origin	51%	52%	53%	54%	54%	56%	57%	57%	57%	57%	55%
Foreign origin^a	49	48	47	46	46	44	43	43	43	43	45
Japan	20	20	19	19	18	16	15	14	13	12	17
West Germany	10	11	10	10	10	10	11	11	11	11	11
U.K.	4	4	4	4	4	4	4	4	4	5	4
France	3	4	4	3	3	3	3	4	4	4	3
Switzerland	2	2	2	2	2	2	2	2	2	3	2
Canada	2	2	1	1	2	1	1	1	1	1	1
Italy	2	1	1	1	1	1	1	1	1	2	1
Netherlands	1	1	1	1	1	1	1	1	1	1	1
Sweden	1	1	1	1	1	1	1	1	1	1	1
Belgium	1	1	1	1	1	1	1	1	1	1	1
U.S.S.R.	—	—	—	—	—	—	—	—	1	1	—

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. a Data for individual countries may not equal this number because of rounding. **Source:** U.S. Patent & Trademark Office

1 R&D Overview

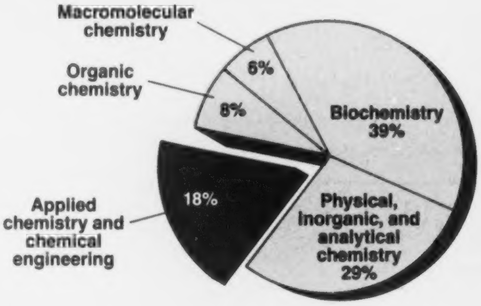
Almost half of U.S. chemical patents are of foreign origin



1989 total U.S. chemical patents issued = 27,035

Source: U.S. Patent & Trademark Office

Applied fields account for about a fifth of chemistry papers



1989 total[a] = 397,158

[a] Number of abstracts of papers published in *Chemical Abstracts*.
Source: Chemical Abstracts Service

PATENT ACTIVITY OF U.S. COMPANIES: Large gain for most chemical and drug firms

Number of patents issued	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	Total 1980–89
CHEMICAL COMPANIES											
Du Pont[a]	495	437	449	371	395	416	387	331	430	349	**4,060**
Dow Chemical	431	421	469	371	335	328	246	276	260	249	**3,386**
Ciba-Geigy	346	279	286	244	305	290	244	281	345	309	**2,929**
Union Carbide	132	141	159	208	242	231	182	202	262	211	**1,970**
American Cyanamid	114	101	107	92	115	111	128	129	188	205	**1,290**
PPG Industries	112	118	118	124	128	137	137	177	189	166	**1,406**
Dow Corning	105	82	58	68	55	52	37	35	50	31	**583**
Ethyl	87	51	48	77	105	76	44	31	43	51	**613**
Monsanto	87	76	91	110	100	138	136	131	211	205	**1,285**
Olin	80	59	58	81	117	112	85	80	80	106	**858**
GAF	50	23	15	12	23	19	21	32	47	48	**290**
Hercules	46	32	50	43	41	39	37	30	52	23	**393**
W. R. Grace	40	46	43	42	45	57	52	49	68	72	**514**
Stauffer Chemical	36	69	94	75	104	95	81	87	94	93	**828**
Rohm & Haas	32	18	22	33	31	37	55	49	77	74	**428**
International Flavors & Fragrances	31	24	38	76	104	95	87	87	96	76	**714**
TOTAL[b]	**2224**	**1977**	**2105**	**2027**	**2245**	**2233**	**1959**	**2007**	**2492**	**2268**	**21,537**
ANNUAL CHANGE	**12%**	**−6%**	**4%**	**−10%**	**1%**	**14%**	**−2%**	**−19%**	**10%**	**23%**	
DRUG COMPANIES											
Merck	173	125	123	103	105	135	114	135	160	156	**1,329**
Warner-Lambert	117	113	118	101	73	49	34	25	37	36	**703**
Hoffmann-LaRoche	93	59	86	84	74	78	90	118	124	144	**950**
Pfizer	79	63	67	72	72	89	61	72	92	75	**742**
American Home Products	76	69	46	38	49	32	24	43	52	52	**481**
Eli Lilly	75	68	85	82	107	80	74	104	112	85	**872**
Squibb	66	74	75	70	74	53	37	56	62	85	**652**
SmithKline Beckman	62	56	54	27	43	68	59	66	59	82	**576**
Upjohn	30	15	26	66	66	107	73	122	337	170	**1,012**
TOTAL[b]	**771**	**642**	**680**	**643**	**663**	**691**	**566**	**741**	**1035**	**885**	**7,317**
ANNUAL CHANGE	**20%**	**–6%**	**6%**	**–3%**	**–4%**	**22%**	**–24%**	**–28%**	**17%**	**5%**	

Note: Includes U.S. chemical and drug companies and U.S. subsidiaries of foreign companies that have received more than 1000 U.S. patents since 1962. a Includes patents issued to Conoco, acquired in 1981, for all years. b These totals include patents issued to companies in this table only. **Source:** U.S. Patent & Trademark Office

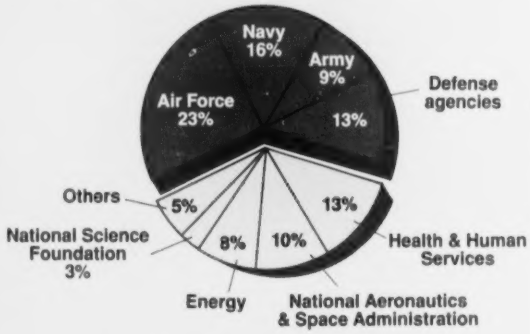
ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS*: Biochemistry's share holds at almost 40%

	1989	1988	1987	1986	1985	1984	1983	1979	Change 1979–89
BIOCHEMISTRY	39.2%	39.7%	40.5%	40.4%	40.5%	40.5%	38.3%	38.8%	0.4%
% of all biochemistry abstracts									
Pharmacology	12.6	12.7	12.6	12.2	12.3	11.6	11.8	11.9	0.7
Mammalian hormones[a]	12.0	12.0	12.2	12.5	12.3	12.4	12.9	5.9	6.1
Mammalian biochemistry[a]	10.7	10.8	11.1	10.8	11.1	11.3	11.1	17.1	−6.4
Biochemical genetics[b]	7.9	7.6	6.7	6.1	5.2	4.2	3.8	—	—
Toxicology	7.8	7.9	8.3	7.8	7.9	8.0	8.5	7.4	0.4
Immunochemistry	6.3	5.8	5.8	6.1	5.3	4.8	4.2	3.2	3.1
Enzymes	6.1	6.1	5.4	5.6	5.6	5.8	6.1	6.4	−0.3
Biochemical methods	5.1	5.1	4.8	5.0	4.9	4.9	4.9	5.4	−0.3
General biochemistry	5.1	5.3	4.6	4.7	4.9	5.3	5.8	7.0	−1.9
Microbial biochemistry[a]	5.1	4.8	5.1	5.7	5.7	5.2	5.1	5.3	−0.2
Plant biochemistry[a]	4.6	5.0	5.3	5.2	5.5	6.2	5.9	5.8	−1.2
Others	16.7	16.9	18.1	18.3	19.3	20.3	19.9	24.6	−7.9
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY	29.0%	28.8%	29.0%	29.8%	29.8%	28.8%	29.6%	28.9%	0.1%
% of all physical, inorganic, and analytical chemistry abstracts									
Nuclear chemistry	19.4	17.8	19.5	19.9	21.8	22.2	22.5	25.1	−5.7
Spectra	18.1	20.0	20.4	20.0	18.4	18.0	17.6	17.0	1.1
Electric phenomena	13.9	12.5	10.9	10.8	10.8	10.8	10.0	11.4	2.5
Crystallography and liquid crystals	7.8	7.0	7.1	7.0	7.5	7.8	8.3	8.2	−0.4
General physical chemistry	6.9	7.2	7.9	7.0	6.9	6.9	7.3	6.6	0.3
Analytical chemistry	5.1	5.7	5.9	6.8	6.1	6.3	6.2	5.6	−0.5
Others	28.8	29.8	28.3	28.5	28.5	28.0	28.1	25.8	3.0
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
APPLIED CHEMISTRY AND CHEMICAL ENGINEERING	18.1%	18.6%	18.0%	18.2%	18.4%	17.6%	19.4%	19.4%	−1.3%
% of all applied chemistry and chemical engineering abstracts									
Metals and alloys	22.1	21.7	20.6	20.8	20.0	18.9	19.1	23.6	−1.5
Water, wastes, and pollution	17.8	20.4	20.4	21.9	20.2	21.0	19.6	20.8	−3.0
Unit operations and processes	10.3	8.0	9.0	7.1	7.5	7.0	7.5	6.1	4.2
Mineralogical and geological chemistry	9.3	11.8	11.2	12.0	12.5	14.6	14.1	15.8	−6.5
Ceramics	9.1	6.7	6.3	5.8	5.6	5.1	5.4	5.0	4.1
Fossil fuels, derivatives, and related products	8.7	8.8	9.6	9.0	10.1	10.1	10.3	7.8	0.9
Pharmaceuticals and pharmaceutical analysis	7.8	7.6	7.8	8.2	8.0	7.0	6.5	5.1	2.7
Others	14.9	15.0	15.1	15.2	16.1	16.3	17.5	15.8	−0.9
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
ORGANIC CHEMISTRY	7.8%	7.3%	6.9%	5.9%	6.4%	7.6%	7.3%	7.6%	0.2%
% of all organic chemistry abstracts									
Physical organic chemistry	25.9	23.0	23.9	27.3	30.6	32.0	30.5	38.8	−12.9
Organometallic and organometalloidal compounds	18.4	15.7	16.1	18.3	16.2	17.1	16.3	8.5	9.9
Heterocyclic compounds[a]	16.1	18.8	19.9	15.0	16.1	15.6	16.2	16.0	0.1
Aromatic compounds[a]	6.9	7.2	7.7	7.3	6.3	6.3	7.1	8.2	−1.3
Carbohydrates	6.5	8.1	5.6	7.8	5.7	5.7	5.8	6.0	0.5
Biomolecules and their synthetic analogs[b]	5.8	6.1	5.8	5.0	4.9	4.4	4.5	—	—
Amino acids, peptides, and proteins[a]	4.5	5.8	4.3	3.9	4.6	4.8	4.5	4.1	0.4
Aliphatic compounds[a]	3.6	4.1	4.9	4.4	4.2	3.6	4.3	6.0	−2.4
Others	12.3	11.2	11.8	11.0	11.4	10.5	10.8	12.4	−0.1
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
MACROMOLECULAR CHEMISTRY	5.9%	5.6%	5.6%	5.7%	4.9%	5.5%	5.4%	5.3%	0.6%
% of all macromolecular chemistry abstracts									
Synthetic high polymers	34.4	34.8	35.2	34.1	34.1	34.0	34.4	26.3	8.1
Plastics manufacture and uses	25.1	23.7	23.6	23.8	25.3	24.2	24.4	27.8	−2.7
Cellulose, lignin, paper, and other wood products	9.2	9.6	8.8	9.8	9.1	9.6	9.1	11.1	−1.9
Textiles	7.2	7.3	8.1	8.8	8.2	7.3	7.9	10.1	−2.9
Synthetic elastomers and natural rubber	5.6	6.7	7.2	6.7	6.8	7.3	7.5	7.6	−2.0
Coatings, inks, and related products	5.6	5.7	5.8	7.2	7.2	7.8	6.6	8.1	−2.5
Others	12.9	12.2	11.3	9.6	9.3	9.8	10.1	9.0	3.9
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—

How to read this table: Using biochemistry as an example, in 1989 39.2% of all the papers abstracted by Chemical Abstracts Service are in the various subdisciplines of biochemistry; 12.6% of all abstracts in biochemistry, in turn, are in the subdiscipline of pharmacology, and so on. **a** Definition of section changed in 1982. **b** New section in 1982. **Source:** Chemical Abstracts Service

Bulk of Federal Funds Still Go to Defense

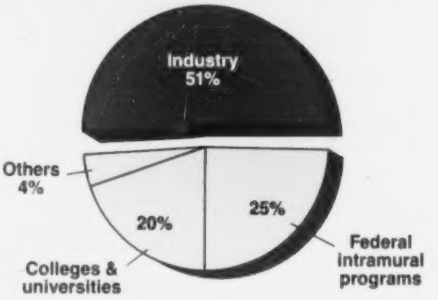
Defense Department contributes more than 60% of federal R&D funding . . .



Estimated fiscal 1990 total federal R&D obligations = $66.1 billion

Source: National Science Foundation

. . . with industrial firms receiving about half of total federal spending



Estimated fiscal 1990 total federal R&D obligations = $66.1 billion

FEDERAL OBLIGATIONS FOR R&D: Growth on hold for Energy, Agriculture, Interior, and Commerce

$ Millions	1990[a]	1989[a]	1988	1987	1986	1985	1984	1983	Annual change 1987–88	Annual change 1983–88
Defense	$40,242	$37,630	$35,415	$35,232	$32,938	$29,792	$25,373	$22,993	1%	9%
Air Force	15,069	15,266	15,034	15,348	13,594	13,261	12,092	10,813	−2	7
Navy	10,373	9,618	9,514	9,508	9,650	9,127	7,606	6,068	0	9
Army	5,843	5,351	4,806	5,020	4,809	4,571	4,226	3,998	−4	4
Defense agencies	8,538	7,189	5,833	5,220	4,767	2,782	1,392	2,052	12	23
Health & Human Services	8,376	7,888	7,158	6,609	5,658	5,451	4,831	4,353	8	10
National Institutes of Health	7,177	6,792	6,291	5,853	5,005	4,828	4,257	3,789	7	11
Alcohol, Drug Abuse & Mental Health Administration	764	679	555	476	396	378	337	302	17	13
National Aeronautics & Space Administration	6,870	5,688	4,330	3,787	3,420	3,327	2,822	2,662	14	10
Energy	5,282	5,479	5,036	4,757	4,688	4,996	4,674	4,537	6	2
National Science Foundation	1,881	1,664	1,532	1,471	1,353	1,346	1,203	1,062	4	8
Agriculture	1,045	1,049	1,017	948	929	943	866	848	7	4
Agricultural Research Service	546	525	506	479	463	470	451	443	6	3
Cooperative State Research Service	279	308	298	271	269	284	236	232	10	5
Forest Service	143	138	136	127	113	113	108	108	7	5
Environmental Protection Agency	421	386	347	348	317	320	261	241	0	8
Interior	388	432	417	404	385	392	411	383	3	2
Geological Survey[b]	231	240	236	227	219	215	209	157	4	8
Commerce	310	406	389	402	399	399	358	335	−3	3
National Oceanic & Atmospheric Administration	178	268	263	286	275	270	244	222	−8	3
National Institute of Standards & Technology	118	123	108	99	101	101	96	95	9	3
Others	1,269	1,157	1,186	1,298	1,325	1,367	1,427	1,300	−9	−2
TOTAL	$66,084	$61,902	$56,935	$55,255	$51,412	$48,332	$42,225	$38,712	3%	8%
ANNUAL CHANGE	7%	9%	3%	7%	6%	14%	9%	6%		

Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

PERFORMERS OF FEDERALLY FUNDED R&D: Academia accounts for about a fifth of the total

Federal obligations, $ millions	1990[a]	1989[a]	1988	1987	1986	1985	1984	1983	Annual change 1987–88	Annual change 1983–88
Industry	$33,401	$31,051	$28,631	$28,628	$25,898	$23,496	$20,219	$18,521	0%	16%
FFRDCs[b] administered by industry	2,071	2,008	1,911	1,860	1,697	1,791	1,608	1,501	3	5
Federal intramural Programs	16,726	15,795	14,281	13,413	13,535	12,945	11,572	10,582	6	6
Universities and colleges	12,977	12,026	11,302	10,545	9,327	9,156	8,033	7,360	7	9
FFRDCs[b] administered by universities	4,151	3,740	3,474	3,210	2,768	2,816	2,486	2,394	8	8
Nonprofit institutions	2,412	2,501	2,188	2,221	2,228	2,388	2,094	1,823	−1	4
FFRDCs[b] administered by nonprofit institutions	556	593	506	511	551	689	597	581	−1	−3
Foreign	409	362	392	295	296	245	176	240	33	10
State and local governments	160	167	142	148	128	129	131	186	−4	−5
TOTAL	$66,084	$61,902	$56,935	$55,253	$51,412	$48,360	$42,225	$36,432	3%	9%

Note: Fiscal years. a Estimated. b Federally funded R&D centers. **Source:** National Science Foundation

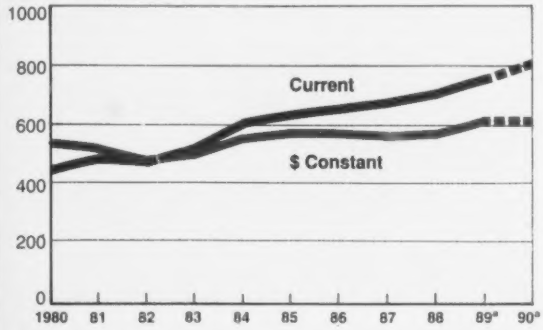
FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Engineering, environmental science slow

$ Millions for research only	1990[a]	1989[a]	1988	1987	1986	1985	1984	1983	Annual change 1987–88	Annual change 1983–88
Life sciences	$ 8,739	$ 8,276	$ 7,724	$ 7,344	$ 6,464	$ 6,366	$ 5,636	$ 5,178	5%	8%
Engineering	4,258	4,364	3,956	3,906	3,739	3,629	3,624	3,517	1	2
Chemical	229	290	258	216	246	254	145	145	19	12
Metallurgy and materials	456	510	457	362	445	439	341	333	12	7
National engineering centers	656	721	678	669	632	664	858	828	6	−4
Physical sciences	3,966	3,726	3,317	3,253	3,069	3,044	2,969	2,891	12	3
Chemistry	808	777	703	680	662	645	606	520	11	6
Physics	2,314	2,185	1,975	1,854	1,806	1,820	1,836	1,855	6	1
Environmental sciences	1,756	1,774	1,607	1,512	1,482	1,404	1,276	1,251	6	5
Mathematical and computer sciences	755	724	643	641	615	578	440	419	0	9
Other sciences	1,617	1,551	1,402	1,288	1,133	1,110	1,034	997	9	7
TOTAL	$21,091	$20,415	$18,649	$17,943	$16,502	$16,130	$14,979	$14,254	4%	6%
ANNUAL CHANGE	3%	9%	4%	9%	2%	8%	5%	9%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

In real dollars, federal support for chemical research changed little during 1980s

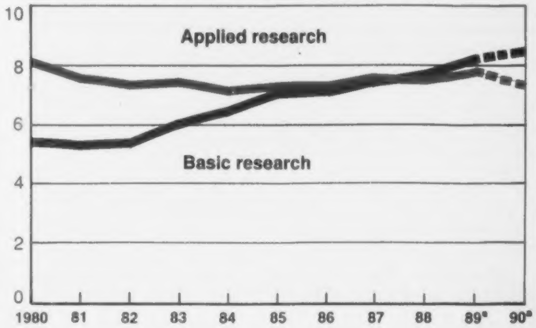
Federal obligations for research, $ millions



Note: Fiscal years. Constant-dollar values calculated by C&EN based on NSF data. a Estimated. **Source:** National Science Foundation

Funding for applied research has stalled but that for basic research climbs steadily

Federal obligations for research, $ billions, constant (1982)



Note: Fiscal years. Constant-dollar values calculated by C&EN based on NSF data. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR BASIC RESEARCH: Health research takes more than 40%

$ Millions	1990[a]	1989[a]	1988	1987	1986	1985	1984	1983	Annual change 1987–88	Annual change 1983–88
Health & Human Services	$ 4,754	$ 4,411	$4081	$3830	$3339	$3233	$2815	$2475	7%	11%
National Institutes of Health	4,347	4,063	3795	3577	3119	3018	2625	2313	7	10
Alcohol, Drug Abuse & Mental Health Administration	360	321	266	232	203	197	171	145	15	13
National Science Foundation	1,754	1,553	1433	1371	1275	1262	1132	999	5	7
National Aeronautics & Space Administration	1,462	1,438	1113	1014	917	751	755	617	10	13
Energy	1,394	1,314	1185	1069	960	943	830	768	12	9
Defense	964	908	877	908	924	861	848	786	−3	2
Navy	390	344	342	354	337	343	316	305	−3	2
Air Force	216	188	196	222	216	198	192	164	−12	4
Army	207	175	166	217	248	241	222	208	−24	−4
Defense agencies	151	201	173	115	122	79	118	108	50	10
Agriculture	512	491	481	446	433	445	393	362	8	6
Agricultural Research Service	295	283	271	253	248	250	241	215	7	5
Cooperative State Research Service	153	145	146	133	132	142	100	99	10	8
Forest Service	54	52	52	49	42	44	41	39	6	6
Interior	129	147	126	135	133	138	126	103	−7	4
Geological Survey[b]	92	94	90	85	83	81	79	65	6	7
Bureau of Mines	32	48	32	46	45	50	41	24	−30	6
Environmental Protection Agency	76	44	27	31	39	39	30	22	−13	4
Commerce	31	32	31	26	27	23	21	19	19	10
National Institute of Standards & Technology	27	28	26	25	26	22	20	18	4	8
Others	125	126	120	116	107	124	119	109	3	2
TOTAL	$11,201	$10,464	$9474	$8944	$8153	$7819	$7067	$6260	6%	9%
ANNUAL CHANGE	7%	10%	6%	10%	4%	11%	13%	14%		

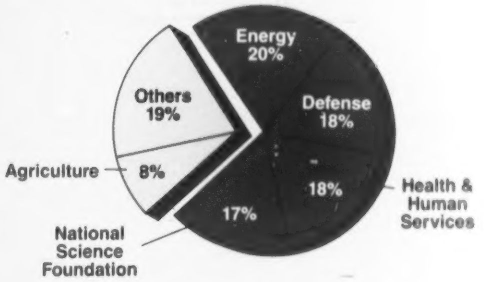
Note: Fiscal years. a Estimated. Includes Office of Water Research & Technology. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR APPLIED RESEARCH: Health outlays edge above those for military

$ Millions	1990[a]	1989[a]	1988	1987	1986	1985	1984	1983	Annual change 1987–88	Annual change 1983–88
Health & Human Services	$ 2796	$2694	$2416	$2195	$1851	$1796	$1652	$1545	-10%	9%
National Institutes of Health	2106	2046	1886	1740	1469	1410	1286	1165	8	10
Alcohol, Drug Abuse & Mental Health Administration	400	355	287	241	192	180	165	155	19	13
Defense	2412	2527	2362	2440	2303	2307	2201	2437	−3	−1
Army	590	582	588	693	579	583	487	485	−15	4
Air Force	581	550	577	563	542	538	548	524	2	2
Navy	411	417	406	432	447	448	450	522	−6	−5
Defense agencies	829	978	791	751	735	738	717	906	5	−3
National Aeronautics & Space Administration	1584	1426	1219	1256	1152	1033	955	928	−3	6
Energy	1000	1105	1051	1029	1081	1198	1195	1193	2	−3
Agriculture	501	526	505	473	464	466	442	456	7	2
Agricultural Research Service	224	215	208	201	188	192	184	203	3	0
Cooperative State Research Service	127	163	153	138	137	143	136	134	11	3
Forest Service	84	81	80	73	68	66	64	65	10	4
Environmental Protection Agency	262	259	241	246	179	176	142	152	−2	10
Commerce	247	326	311	313	313	301	276	266	−1	3
National Oceanic & Atmospheric Administration	158	234	225	234	237	224	198	189	−4	4
National Institute of Standards & Technology	80	82	73	64	63	65	64	63	14	3
Interior	237	259	266	247	235	231	254	255	8	1
Geological Survey[b]	127	133	136	132	128	130	125	90	3	9
National Science Foundation	127	110	100	99	78	84	71	63	1	10
Others	725	719	705	700	693	720	725	699	1	0
TOTAL	$ 9891	$9951	$9176	$8999	$8349	$8312	$7911	$7993	2%	3%
ANNUAL CHANGE	−1%	8%	2%	8%	0%	5%	−1%	6%		

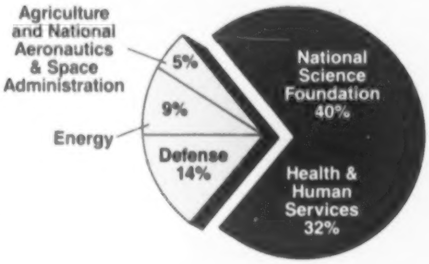
Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

Four agencies dominate government funding for chemical research...



Estimated fiscal 1990 federal chemistry research obligations = $808 million

...but at universities, NSF and HHS alone provide most of the money



Estimated fiscal 1990 federal chemistry university research obligations = $324 million[a]

[a] Total is for these six agencies only. **Source:** National Science Foundation

UNIVERSITY RESEARCH: Life sciences continue to garner most government support

									Annual change	
Federal obligations, $ millions	1990	1989[a]	1988[a]	1987	1986	1985	1984	1983	1987–88	1983–88
Life sciences	$4595	$4227	$4029	$3824	$3252	$3192	$2800	$2460	5%	10%
Physical sciences	985	918	857	823	752	750	698	597	4	8
Chemistry	324	310	295	281	266	267	242	206	5	7
Physics	497	461	425	404	405	402	375	329	5	5
Engineering	751	700	673	600	609	507	474	409	12	10
Chemical	56	66	57	55	51	46	51	24	4	19
Metallurgy and materials	161	158	175	108	133	107	88	86	62	15
Environmental sciences	474	449	408	400	366	361	320	317	2	5
Mathematical and computer sciences	385	357	305	289	274	253	182	172	6	12
Other sciences	603	559	494	449	365	348	304	298	10	11
TOTAL	$7793	$7210	$6766	$6384	$5617	$5411	$4777	$4252	8%	10%
ANNUAL CHANGE	8%	7%	6%	14%	4%	13%	12%	12%		

Note: Fiscal years. Includes funding only from six agencies that together represent approximately 97% of federal research support to universities. a Estimated. **Source:** National Science Foundation

UNIVERSITY RESEARCH IN CHEMISTRY: NSF, NIH, and DOD provide 85% of total

									Annual change	
Federal obligations, $ millions	1990[a]	1989[a]	1988	1987	1986	1985	1984	1983	1987–88	1983–88
National Science Foundation	$128.4	$117.8	$111.6	$107.1	$103.5	$108.1	$100.7	$ 84.7	4%	6%
Health & Human Services	104.9	95.7	91.4	85.0	75.0	75.2	63.2	51.9	8	12
National Institutes of Health	102.1	93.2	89.3	83.4	74.4	74.7	62.8	51.4	7	12
Alcohol, Drug Abuse & Mental Health Administration	2.7	2.4	2.1	1.6	0.6	0.6	0.4	0.5	31	33
Defense	44.4	42.8	41.3	45.0	43.2	40.4	34.7	29.1	−8	7
Air Force	18.5	16.3	17.0	18.4	16.1	14.0	na	9.6	−8	12
Navy	16.0	13.9	13.6	17.2	13.9	15.5	na	11.7	−21	3
Army	8.7	8.2	8.8	8.3	12.4	10.9	na	7.8	6	2
Defense agencies	1.2	4.4	1.8	1.1	0.9	0	na	0	64	0
Energy	29.5	36.5	33.8	28.5	27.6	26.0	26.3	18.6	19	13
Agriculture	10.7	12.3	11.8	11.2	12.2	15.5	13.5	14.5	5	−4
National Aeronautics & Space Administration	5.9	5.1	4.8	4.3	4.2	4.1	4.1	4.6	12	1
TOTAL	$323.7	$310.3	$294.7	$281.1	$265.7	$269.4	$242.3	$205.7	5%	7%
ANNUAL CHANGE	4%	5%	5%	6%	−1%	11%	18%	na		

Note: Fiscal years. Data from these six agencies represent approximately 97% of federal obligations for 1990. a Estimated. na = not available. **Source:** National Science Foundation

2 R&D Federal Government

FEDERAL OBLIGATIONS FOR DEVELOPMENT: Vast majority of outlays still go to defense

$ Millions	1990[a]	1989[a]	1988	1987	1986	1985	1984	1983	Annual change 1987–88	Annual change 1983–88
Defense	$36,866	$34,195	$32,176	$31,884	$29,711	$26,623	$22,324	$19,770	1%	10%
Air Force	14,272	14,528	14,261	14,563	12,835	12,524	11,352	10,124	−2	7
Navy	9,571	8,856	8,766	8,721	8,866	8,336	6,840	5,241	1	11
Army	5,045	4,594	4,052	4,110	3,982	3,747	3,517	3,305	−1	4
Defense agencies	7,558	6,010	4,868	4,354	3,911	1,965	557	1,039	12	36
National Aeronautics & Space Administration	3,824	2,824	1,999	1,518	1,351	1,544	1,113	1,117	32	12
Energy	2,888	3,060	2,801	2,659	2,648	2,825	2,649	2,576	5	2
Health & Human Services	826	783	661	584	468	423	365	332	13	15
National Institutes of Health	725	682	610	536	418	400	347	311	13	14
Environmental Protection Agency	82	82	80	71	100	106	89	66	13	17
Commerce	37	47	47	64	60	75	62	50	−26	−1
National Oceanic & Atmospheric Administration	17	31	35	52	37	45	47	33	−33	1
National Institute of Standards & Technology	12	14	9	9	12	14	12	14	0	−8
Agriculture	32	31	31	29	32	32	31	10	7	25
Agricultural Research Service	27	26	26	24	27	28	27	26	8	0
Interior	22	26	24	22	17	22	31	25	9	−1
Geological Survey[b]	13	13	11	10	7	4	5	2	10	41
National Science Foundation	0	0	0	0	0	0	0	0	0	0
Others	416	439	466	482	524	553	583	493	−3	−1
TOTAL	$44,993	$41,487	$38,285	$37,313	$34,910	$32,202	$27,246	$24,458	2%	9%
ANNUAL CHANGE	8%	8%	3%	7%	8%	18%	11%	4%		

Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

ENGINEERING RESEARCH: Overall government support is declining slightly in 1990, but for

Federal obligations, $ millions	1990[a] All engineering	1990[a] Chemical engineering	1990[a] Metallurgy & materials	1989[a] All engineering	1989[a] Chemical engineering	1989[a] Metallurgy & materials	1988 All engineering	1988 Chemical engineering
Defense	$1599.9	$ 49.2	$285.0	$1729.0	$ 47.5	$331.0	$1636.1	$ 41.9
Air Force	466.4	3.3	42.9	434.6	3.2	38.8	455.1	1.8
Army	400.4	24.4	27.1	367.2	23.7	23.9	384.4	20.3
Navy	391.5	20.8	54.8	375.4	18.9	51.9	379.8	19.6
Defense agencies	341.5	0.7	160.1	551.7	1.7	216.2	416.8	0.1
National Aeronautics & Space Administration	1485.7	2.3	25.2	1362.4	1.9	22.4	1138.2	2.0
Energy	377.3	74.2	78.2	500.0	145.5	78.8	479.5	134.5
National Science Foundation	288.1	49.6	30.5	231.9	42.4	28.1	206.8	38.9
Transportation	78.8	5.2	0.7	81.2	7.4	0.3	71.9	1.0
Interior	73.2	4.7	23.6	97.3	4.9	35.1	85.3	5.1
Environmental Protection Agency	58.4	28.9	0.9	57.3	29.2	1.3	50.7	24.2
Commerce	49.7	5.9	12.4	55.8	3.5	12.5	49.3	2.7
Agriculture	32.4	8.1	0	32.1	7.8	0	31.7	7.7
Others	234.3	0	0	218.7	0.1	0	206.7	0.1
TOTAL	$4257.8	$229.1	$456.5	$4363.7	$290.2	$509.5	$39[illegible].2	$258.1
ANNUAL CHANGE	−2%	−21.1%	−10%	10%	12%	11%	1%	20%

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR CHEMICAL RESEARCH: Increases have been moderate since 1985

									Annual change	
$ Millions	1990[a]	1989[a]	1988	1987	1986	1985	1984	1983	1987–88	1983–88
Energy	$165.2	$171.8	$162.9	$145.5	$145.9	$143.0	$140.4	$117.6	12%	7%
Defense	146.2	125.2	125.0	144.9	163.4	156.4	139.8	121.8	−13	1
Army	71.7	55.4	57.5	72.2	81.4	78.2	66.3	59.3	−20	−1
Air Force	46.2	41.7	43.6	43.3	42.0	39.5	36.7	31.2	1	7
Navy	27.1	23.7	22.1	28.4	39.1	38.3	36.6	31.1	−22	−7
Defense agencies	1.2	4.4	1.8	1.1	0.9	0.4	0.3	0.3	64	43
Health & Human Services	143.9	134.9	123.8	115.5	104.2	99.1	86.3	74.2	7	11
National Institutes of Health	130.3	122.8	114.4	108.1	99.5	95.1	84.1	72.2	6	10
Alcohol, Drug Abuse & Mental Health Administration	13.7	12.1	9.4	7.4	4.7	4.0	2.3	2.0	27	36
National Science Foundation	139.3	126.8	120.6	115.3	112.6	115.6	109.9	92.4	5	0
Agriculture	61.2	60.9	60.8	65.0	58.6	58.0	69.0	63.8	−6	−1
Agricultural Research Service	42.1	40.5	40.9	46.4	40.0	36.1	51.6	49.5	−11	−4
Cooperative State Research Service	11.1	12.7	12.2	11.5	12.4	16.1	13.5	10.8	6	2
Forest Service	8.0	7.8	7.6	7.1	6.2	5.7	3.9	3.6	7	16
National Aeronautics & Space Administration	50.1	56.6	27.5	13.4	11.8	16.3	7.3	9.4	105	24
Environmental Protection Agency	42.7	36.5	30.6	34.6	20.1	17.5	15.9	14.8	−12	16
Commerce	24.6	24.8	23.6	22.9	19.1	17.7	15.3	14.0	3	11
National Institute of Standards & Technology	18.6	18.1	16.9	16.5	16.4	15.4	14.1	12.7	2	6
National Oceanic & Atmospheric Administration	6.0	6.7	6.7	6.4	2.4	1.4	1.3	1.2	5	41
Interior	21.4	22.2	21.9	20.9	20.3	19.4	19.2	6.2	5	29
Geological Survey[b]	20.9	21.9	21.7	20.8	20.2	19.4	18.4	5.6	4	31
Others	13.3	17.6	6.4	2.4	6.3	1.5	3.3	6.1	167	1
TOTAL	$807.9	$777.3	$703.1	$680.3	$662.4	$644.5	$606.4	$520.3	3%	6%
ANNUAL CHANGE	4%	11%	3%	3%	3%	6%	17%	8%		

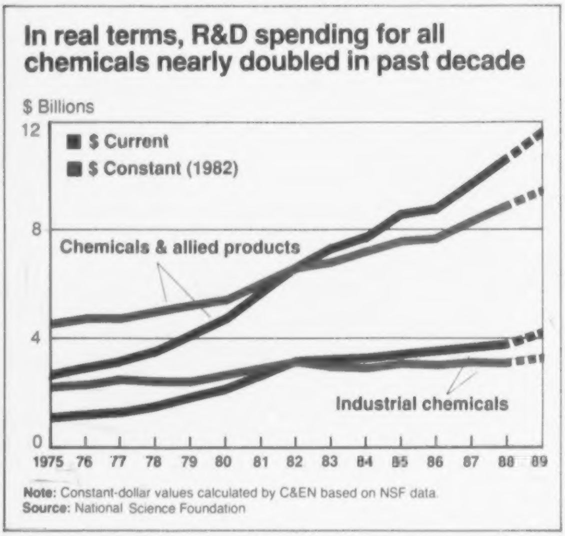
Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

chemical engineering the decline in funding is substantial

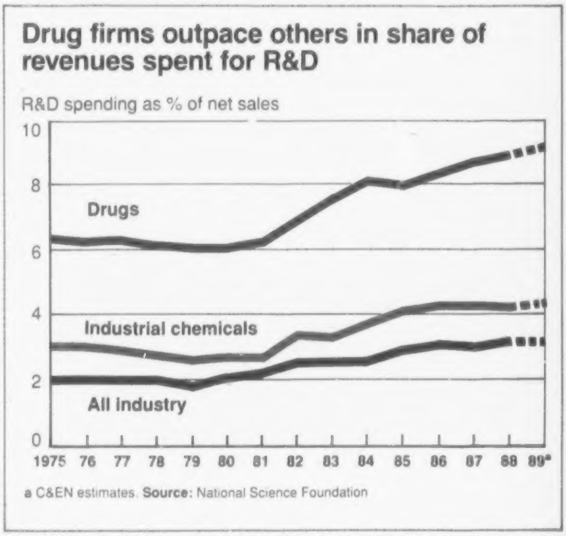
1988	1987			1986			1985		
Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials
$294.4	$1629.7	$ 46.9	$203.6	$1505.6	$ 50.3	$253.7	$1502.0	$ 53.3	$260.9
43.2	460.3	1.8	34.5	444.7	1.9	33.4	423.9	1.7	28.6
23.8	442.4	23.8	32.1	373.6	24.0	26.8	344.3	26.7	42.2
52.5	401.5	21.3	57.2	397.8	24.4	117.4	421.2	24.8	121.1
174.6	325.6	0	79.8	289.5	0	76.2	312.6	0.1	69.0
18.8	1170.5	1.5	19.9	1066.9	1.0	16.2	931.6	0.6	15.8
78.4	442.2	88.9	77.1	494.2	121.6	82.8	511.3	136.6	68.4
25.6	191.7	37.3	22.9	199.1	33.4	43.5	193.3	32.6	42.7
3.6	48.1	1.0	0.7	52.8	1.9	1.8	49.4	0.6	1.5
24.8	87.8	5.0	28.5	93.2	4.7	38.5	100.2	4.8	39.8
0.3	55.4	25.6	0.5	48.6	23.9	0.5	44.6	18.0	2.6
10.6	41.3	2.4	8.6	41.7	2.6	7.6	39.8	1.7	6.9
0	33.9	6.9	0	31.1	6.0	0	28.7	5.6	0
0.2	205.8	0.3	0.2	205.9	0.4	0.5	227.4	0.3	0.5
$456.7	$3906.2	$215.8	$362.0	$3738.9	$245.8	$445.0	$3628.5	$254.1	$439.1
26%	4%	−12%	−19%	3%	−3%	1%	0%	76%	29%

3 R&D Industry

Chemical Industry R&D Rose 11% in 1989


In real terms, R&D spending for all chemicals nearly doubled in past decade

Note: Constant-dollar values calculated by C&EN based on NSF data.
Source: National Science Foundation


Drug firms outpace others in share of revenues spent for R&D

a C&EN estimates. **Source:** National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Outlays edge above the $100 billion mark

$ Millions	1989[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Chemicals and allied products	$ 11,900	$10,774	$ 9,878	$ 8,843	$ 8,540	$ 7,927	$ 7,185	$ 6,604	$ 5,625	$ 4,636	$ 4,038	$ 3,580	9%	11%
Industrial chemicals	4,250	3,959	3,901	3,552	3,498	3,240	3,214	3,206	2,802	2,197	1,962	1,798	1	8
Drugs	5,400	4,737	4,108[a]	3,658	3,490[a]	3,316[a]	2,901[a]	2,481[a]	2,073[a]	1,777	1,517	1,308	16	14
Other chemicals	2,250	2,078	1,869[a]	1,633	1,552[a]	1,371[a]	1,070[a]	917[a]	750[a]	662	559	474	12	16
Other industries	91,100	88,648	84,239	79,336	75,699	66,873	$58,083	52,046	46,185	39,869	34,188	29,724	5	11
TOTAL	$103,000	$99,422	$94,117	$88,179	$84,239	$74,800	$65,268	$58,650	$51,810	$44,505	$38,226	$33,304	5%	11%

a C&EN estimates. **Source:** National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Growth for chemicals outstrips that for other industries

$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Chemicals and allied products	$10,580	$ 9,685	$ 8,664	$ 8,310	$ 7,736	$ 6,792	$ 6,197	$ 5,205	$ 4,264	$ 3,692	$ 3,250	9%	13%
Industrial chemicals	3,767	3,714	3,374	3,281	3,057	2,828	2,810	2,393	1,856	1,617	1,473	1	10
Drugs	4,735	4,139	3,657	3,481	3,310	2,896	2,473	2,064	1,756	1,516[a]	1,304[a]	14	14
Other chemicals	2,078	1,832	1,633	1,548	1,369	1,068	914	747	653	559[a]	473[a]	13	16
Other industries	55,883	53,121	51,268	48,733	43,668	37,796	33,908	30,223	26,212	22,016	18,865	5	11
TOTAL	$66,463	$62,806	$59,932	$57,043	$51,404	$44,588	$40,105	$35,428	$30,476	$25,708	$22,115	6%	12%

a C&EN estimates. **Source:** National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Chemical industry gets less than 1% of total

$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Chemicals and allied products	**$ 195**	**$ 192**	**$ 179**	**$ 230**	**$ 191[a]**	**$ 393**	**$ 407**	**$ 421**	**$ 372**	**$ 346**	**$ 330**	2%	−5%[a]
Industrial chemicals	192	187	178	217	183[a]	386	396	409	341	345	325	3	−5[a]
Drugs and other chemicals	3	5	1	13	8	7	11	12	31	1	5	—	—
Other industries	**32,764**	**31,119**	**28,068**	**26,966**	**23,205**	**20,287**	**18,138**	**15,961**	**13,657**	**12,172**	**10,859**	**5**	**12**
TOTAL	**$32,959**	**$31,311**	**$28,247**	**$27,196**	**$23,396**	**$20,680**	**$18,545**	**$16,382**	**$14,029**	**$12,518**	**$11,189**	5%	**11%**

a The decline in 1984 from 1983 results from the administration of federally funded Oak Ridge National Laboratory being changed from a chemical company to a company in the aircraft and missile industry. **Source:** National Science Foundation

COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: Chemicals top all industry for a change

$ Thousands	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Chemicals and allied products	**$140.6**	**$132.8**	**$118.9**	**$116.3**	**$112.5**	**$104.8**	**$102.5**	**$ 96.6**	**$ 87.4**	**$79.6**	**$72.8**
Industrial chemicals	a	a	144.1	144.6	132.0	123.1	122.1	118.0	103.4	92.8	84.2
Drugs	141.5	a	120.1	a	a	103.1	a	a	79.2	71.4	64.8
Other chemicals	a	a	84.6	a	a	a	a	a	66.5	66.5	61.6
All industry	**$138.7**	**$133.9**	**$128.9**	**$130.2**	**$124.0**	**$116.0**	**$111.6**	**$103.9**	**$ 94.9**	**$87.4**	**$80.4**

a Not separately available but included in chemicals and allied products. **Source:** National Science Foundation

R&D BY U.S. COMPANIES ABROAD: Spending by chemical firms is escalating rapidly

$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Chemicals and allied products	**$1540**	**$1243**	**$1071**	**$ 843**	**$ 786**	**$ 729**	**$ 682**	**$ 715**	**$ 603**	**$ 500**	**$ 395**	24%	15%
Industrial and other chemicals	774	625	579	444	385	368	319	287	246	199	151	24	18
Drugs	766	618	492	399	401	361	363	428	357	301	244	23	12
Other industries	**4708**	**3983**	**3553**	**2807**	**2847**	**2540**	**2412**	**2679**	**2562**	**2254**	**1814**	**18**	**10**
TOTAL	**$6248**	**$5226**	**$4624**	**$3650**	**$3633**	**$3269**	**$3094**	**$3393**	**$3165**	**$2754**	**$2209**	20%	11%

Source: National Science Foundation

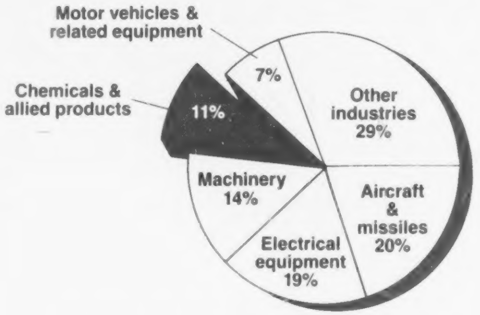
CHEMICAL R&D SPENDING: Growth in company budgets slowed last year

$ Millions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1989 R&D spending as % of sales
Du Pont	$1387	$1319	$1223	$1156	$1144	$1097	$ 966	$ 879	$ 718	$ 591	$ 509	3.9%
Dow Chemical	873	772	670	605	547	507	492	460	404	314	269	5.0
Monsanto	598	648	615	596	470	370	290	264	233	208	161	6.9
American Cyanamid	406	365	314	278	251	232	208	185	166	148	130	8.4
Union Carbide[a]	181	159	159	148	275	265	245	240	207	166	161	2.1
Rohm & Haas	175	156	142	133	124	109	100	92	77	67	54	6.6
W. R. Grace	125	119	107	94	92	81	73	64	57	45	42	2.0
Hercules	79	74	74	71	76	72	74	74	65	57	50	2.6
Air Products	71	72	57	61	51	44	40	37	32	30	24	2.7
Lubrizol	70	65	62	51	44	33	37	36	33	28	23	5.7
Olin	66	58	62	56	53	52	49	45	38	31	26	2.6
Ethyl	61[b]	59[b]	50	47	47	40	39	39	37	34	29	4.0
International Flavors	52	50	45	39	34	32	32	31	30	29	27	6.0
Nalco Chemical	41	37	35	33	32	32	30	33	30	28	21	3.8
TOTAL	**$4185**	**$3953**	**$3615**	**$3368**	**$3240**	**$2966**	**$2675**	**$2479**	**$2127**	**$1776**	**$1526**	**4.3%**
ANNUAL CHANGE	**6%**	**9%**	**7%**	**4%**	**9%**	**11%**	**8%**	**17%**	**20%**	**16%**	**12%**	

Note: Prior years not restated to reflect company revisions. **a** Union Carbide divested a substantial part of its business in 1986; on a pro forma basis, R&D spending was $181 million in 1985 and $178 million in 1984. **b** Adjusted to reflect spin-off of Tredegar Industries. **Source:** Company data

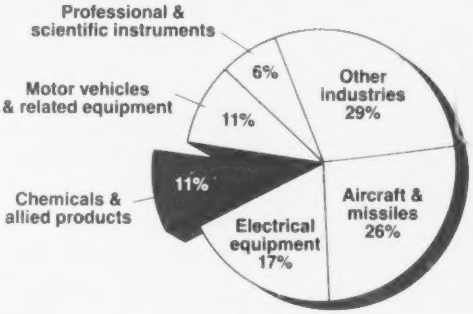
3 R&D Industry

Chemical firms provide work for 11% of R&D scientists and engineers in industry...



1989 total industrial R&D scientists and engineers[a] = 724,900

...and also account for 11% of total industrial R&D outlays in the U.S.



1989 total industrial R&D expenditures = $99.4 million

[a] Full-time equivalent as of January 1989. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Total rises only slightly

Thousands	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
Chemicals and allied products	**77.4**	**75.8**	**73.0**	**75.8**	**71.1**	**69.8**	**67.3**	**61.6**	**54.7**	**51.4**	**50.0**	2%	4%
Industrial chemicals	22.0[a]	22.5[a]	24.4	24.9	23.5	25.6	26.6	25.9	21.6	20.9	21.4	1	0
Drugs	33.9	33.0	29.1	31.8	30.8	30.8[a]	28.2	25.6	23.3	21.6	20.8	3	5
Other chemicals	20.7[a]	20.3	19.5	19.1	16.7	13.4	12.1	10.1	9.8	8.9	7.8	2	9
Other industries	**647.5**	**632.8**	**624.3**	**595.2**	**551.4**	**514.3**	**473.6**	**448.2**	**433.1**	**399.2**	**373.9**	2	6
TOTAL	**724.9**	**708.6**	**697.3**	**671.0**	**622.5**	**584.1**	**540.9**	**509.8**	**487.8**	**450.6**	**423.9**	2%	6%

Note: Data as of January of each year for full-time equivalent personnel. a C&EN estimates. **Source:** National Science Foundation

CHEMISTS IN INDUSTRY: More than half work in some sector of the chemical industry

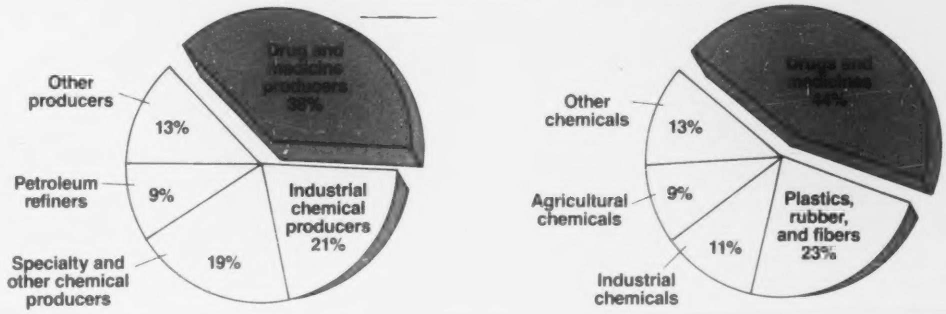
Industry	% of industrial chemists All chemists	% of industrial chemists B.S.	% of industrial chemists M.S.	% of industrial chemists Ph.D.	Mean salary ($ thousands)[a] B.S.	Mean salary ($ thousands)[a] M.S.	Mean salary ($ thousands)[a] Ph.D.
Pharmaceuticals[b]	19%	17%	21%	19%	$44.0	$52.1	$69.8
Specialty chemicals	15	14	13	17	44.8	52.9	64.8
Basic chemicals	6	4	5	8	45.9	53.5	65.6
Plastics	5	4	5	6	45.6	53.8	66.3
Coatings	4	6	5	3	44.5	51.6	61.2
Petroleum and natural gas	4	4	4	5	48.4	56.5	71.3
Agricultural chemicals	4	3	4	5	41.7	48.7	63.6
Electronics	4	3	3	4	45.6	51.8	67.2
Food	3	4	4	3	43.4	51.8	65.8
Aerospace	3	2	3	3	46.8	54.4	63.3
Biochemical products	2	1	2	2	42.8	51.2	66.8
Metals and minerals	2	3	2	1	40.7	50.6	62.2
Rubber	2	3	2	1	44.8	53.3	60.5
Soaps and detergents	1	2	1	1	45.9	53.3	63.5
Paper	1	1	1	1	42.1	56.8	60.4
Other manufacturing	13	14	13	12	42.2	53.2	65.1
Nonmanufacturing	15	15	13	9	43.4	52.7	63.4

a As of March 1, 1990; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. b Includes personal care products.
Source: ACS survey

Drug companies perform the largest share of chemical R&D...

...and research on drugs takes up the biggest part of such R&D funds

1987 chemical R&D spending[a] = $4.4 billion



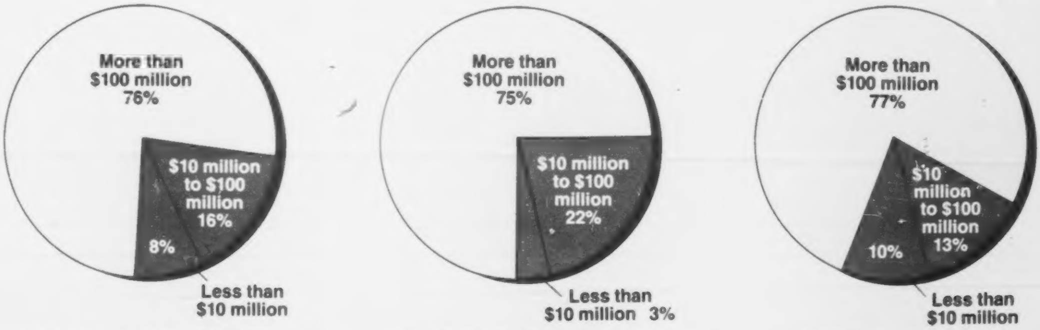
a Excludes basic research. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: Almost 100 for drug companies

	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Chemicals and allied products	**68**	**70**	**57**	**57**	**54**	**51**	**44**	**42**	**42**	**43**	**42**
Industrial chemicals	53	56	39	41	45	44	37	36	36	38	38
Drugs	97	98	81	89	82	74	66	60	62	65	62
Other chemicals	59	63	62	51	39	37	33	30	27	27	29
All industry	**45**	**45**	**43**	**40**	**34**	**33**	**29**	**27**	**27**	**27**	**27**

Source: National Science Foundation

Chemical firms with largest research budgets do at least three fourths of all chemical R&D



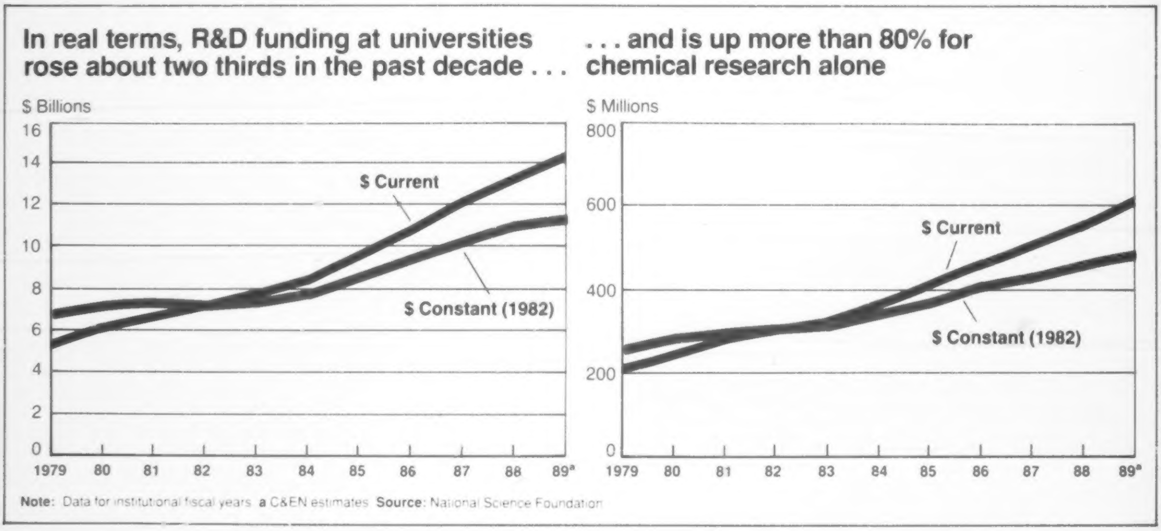
1988 chemicals and allied products R&D funds = $10.8 billion

1988 industrial chemicals R&D funds = $4.0 billion

1988 industry R&D funds = $99.4 billion

Note: Ranges indicate size of companies' 1988 R&D program. **Source:** National Science Foundation

Universities' R&D Outlays Top $13 Billion


In real terms, R&D funding at universities rose about two thirds in the past decade . . .

. . . and is up more than 80% for chemical research alone

Note: Data for institutional fiscal years. a C&EN estimates. **Source:** National Science Foundation

CHARACTER OF UNIVERSITY R&D SPENDING: Funds for applied work rose sharply in 1988

$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978ª	Annual change 1987–88	Annual change 1978–88
Basic research	$ 8,870	$ 8,343	$ 7,476	$6539	$5709	$5288	$4864	$4578	$4024	$3612	$3176	6%	11%
Applied research and development	4,552	3,737	3,428	3124	2885	2576	2442	2267	2037	1749	1449	22	12
TOTAL	**$13,422**	**$12,080**	**$10,904**	**$9663**	**$8594**	**$7864**	**$7306**	**$6829**	**$6062**	**$5361**	**$4625**	**11%**	**11%**
ANNUAL CHANGE	**11%**	**11%**	**13%**	**12%**	**9%**	**8%**	**7%**	**13%**	**13%**	**16%**	**14%**		

Note: Data for institutional fiscal years. Data since 1980 were revised in 1988. a NSF estimates, based on data from Ph.D.-granting institutions only. **Source:** National Science Foundation

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SOURCE OF UNIVERSITY R&D FUNDS: Industry's support up 18% annually in past decade

$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978ª	Annual change 1987–88	Annual change 1978–88
Federal government	$ 8,165	$ 7,328	$ 6,702	$6056	$5416	$4980	$4759	$4561	$4096	$3595	$3059	11%	10%
Institutional funds	2,314	2,114	1,858	1609	1406	1297	1106	995	835	728	623	9	14
State and local governments	1,123	1,020	913	748	686	623	614	546	491	470	414	10	11
Industry	892	807	717	561	474	389	339	294	238	194	170	11	18
Other sources	**928**	**810**	**713**	**690**	**612**	**578**	**489**	**434**	**401**	**374**	**359**	**15**	**10**
TOTAL	**$13,422**	**$12,080**	**$10,904**	**$9663**	**$8594**	**$7864**	**$7306**	**$6829**	**$6062**	**$5361**	**$4625**	**11%**	**11%**

Note: Data for institutional fiscal years. Data since 1980 were revised in 1988. a NSF estimates, based on data from Ph.D.-granting institutions only. **Source:** National Science Foundation

FIELDS OF UNIVERSITY R&D SPENDING: 5% of total goes to chemistry and chemical engineering

												Annual change	
$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978[a]	1987–88	1978–88
All sciences	$11,338	$10,195	$ 9,267	$8250	$7375	$6741	$6273	$5861	$5196	$4593	$4024	11%	11%
Life	7,236	6,476	5,885	5272	4706	4299	4008	3689	3218	2833	2538	12	11
Physical	1,532	1,382	1,281	1144	995	899	823	765	678	602	469	11	13
Physics	726	662	628	549	471	417	366	357	322	292	235	10	12
Chemistry	566	510	469	422	372	335	308	285	245	206	183	11	12
Environmental	891	828	773	702	645	617	558	550	509	453	379	8	9
Psychology and social	764	688	629	534	504	479	483	494	453	396	367	11	8
Computer	410	372	321	281	224	175	149	132	114	98	67	10	20
Mathematical	199	178	152	128	123	106	96	87	79	79	59	12	13
Others	308	271	226	185	179	165	156	145	146	134	117	14	10
Engineering	**2,084**	**1,885**	**1,636**	**1414**	**1219**	**1124**	**1034**	**968**	**866**	**768**	**601**	**11**	**13**
Chemical	154	140	125	109	95	91	83	76	68	na	na	10	—
TOTAL	**$13,422**	**$12,080**	**$10,904**	**$9663**	**$8594**	**$7864**	**$7306**	**$6829**	**$6062**	**$5361**	**$4625**	**11%**	**11%**
ANNUAL CHANGE	**11%**	**11%**	**13%**	**12%**	**9%**	**8%**	**7%**	**13%**	**13%**	**16%**	**14%**		

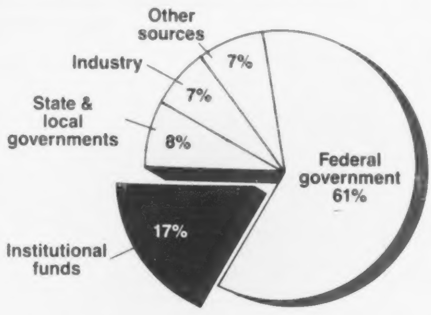
Note: Data for institutional fiscal years. Data since 1980 were revised in 1988. **a** NSF estimates, based on data from Ph.D-granting institutions only. **na** = not available. **Source:** National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Steady growth continues

												Annual change	
$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978[a]	1987–88	1978–88
All sciences	$6940	$6220	$5726	$5190	$4637	$4240	$4061	$3898	$3500	$3069	$2651	12%	10%
Life	4311	3827	3491	3186	2828	2587	2503	2365	2094	1819	1626	13	10
Physical	1145	1042	979	888	779	700	650	619	555	491	392	10	11
Physics	573	528	509	452	389	342	306	309	280	253	199	9	11
Chemistry	403	365	338	313	279	248	230	217	190	157	138	10	11
Environmental	584	542	517	473	446	426	391	391	372	329	275	8	8
Psychology and social	328	295	286	259	241	236	250	280	263	227	204	11	5
Computer	289	257	232	195	163	128	107	93	77	69	41	12	22
Mathematical	149	132	114	97	92	76	72	68	61	60	44	13	13
Others	134	126	107	92	87	87	88	82	78	73	68	6	7
Engineering	**1225**	**1108**	**975**	**866**	**780**	**739**	**697**	**662**	**596**	**526**	**408**	**11**	**12**
Chemical	79	69	66	58	54	52	50	48	46	na	na	14	—
TOTAL	**$8165**	**$7328**	**$6702**	**$6056**	**$5417**	**$4980**	**$4759**	**$4561**	**$4096**	**$3595**	**$3059**	**11%**	**10%**
ANNUAL CHANGE	**11%**	**9%**	**11%**	**12%**	**9%**	**5%**	**4%**	**11%**	**14%**	**18%**	**12%**		

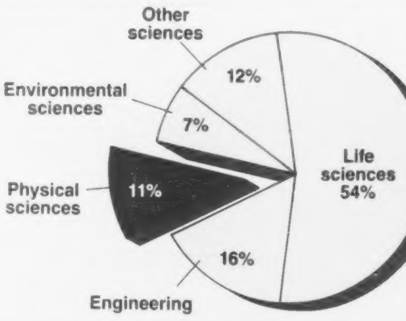
Note: Data for institutional fiscal years. Data since 1980 were revised in 1988. **a** NSF estimates, based on data from Ph.D.-granting institutions only. **na** = not available. **Source:** National Science Foundation

Academic institutions fund less than a fifth of all academic R&D . . .



Fiscal 1988 academic R&D expenditures = $13.4 billion

. . . only about one tenth of which is in physical sciences



Fiscal 1988 academic R&D expenditures = $13.4 billion

Source: National Science Foundation

TOP 10 UNIVERSITY R&D CENTERS: They account for 96% of federal support at all centers

$ Millions, fiscal 1988	Physical sciences	Engineering	Math & computer sciences	Environmental sciences	Life sciences	Psychology & social sciences	Other sciences	Total
1 **Jet Propulsion Lab**	$ 124.7	$ 442.0	$391.0	$101.5	$ 0	$ 0	$0	**$1059.3**
2 **Lawrence Livermore Lab**	285.0	457.0	138.6	31.6	26.9	0	0	**939.1**
3 **Los Alamos National Lab**	426.3	298.8	77.3	21.0	29.5	26.1	3.4	**882.4**
4 **Lincoln Lab**	72.9	273.2	39.7	0	0	0.4	0	**386.2**
5 **Argonne National Lab**	93.4	134.9	5.4	57.1	12.5	0	0	**303.3**
6 **Brookhaven National Lab**	169.1	36.9	0.6	7.4	19.3	0.6	0.2	**234.2**
7 **Lawrence Berkeley Lab**	138.6	0.1	2.3	11.2	25.0	0	6.0	**183.2**
8 **Fermi National Accelerator Lab**	168.7	0	0	0	4.5	0	0	**173.2**
9 **Plasma Physics Lab**	103.5	0	0	0	0	0	0	**103.5**
10 **Stanford Linear Accelerator Center**	98.0	0	0	0	0	0	0	**98.0**
All others	76.1	4.4	20.6	59.6	5.7	1.7	0	**168.1**
TOTAL, ALL FEDERALLY FUNDED R&D CENTERS	**$1756.4**	**$1647.4**	**$675.5**	**$289.4**	**$123.5**	**$28.8**	**$9.6**	**$4530.6**

Note: Data for university-administered, federally funded R&D centers. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal 1988 comparisons with data reported in earlier years may be inappropriate in some areas. **Source:** National Science Foundation

CAPITAL SPENDING AT UNIVERSITIES: Funds for physical sciences jump nearly a third

	1988							Annual change	
$ Millions	Total spending	% federal funds	1987	1986	1985	1984	1983	1987–88	1983–88
All sciences	**$1600.4**	**10%**	**$1367.5**	**$1184.3**	**$1045.8**	**$1028.8**	**$ 956.4**	**17%**	**11%**
Life sciences	1056.4	7	915.1	772.0	697.7	717.0	668.5	15	10
Physical sciences	209.2	18	159.7	144.0	115.7	110.7	98.1	31	16
Mathematical and computer sciences	96.3	0	83.4	90.6	77.2	48.9	54.2	15	12
Psychology and social sciences	92.0	0	65.0	67.7	73.6	78.3	57.7	42	10
Environmental sciences	58.6	0	54.2	49.0	54.6	36.4	42.2	8	7
Other sciences	87.9	0	90.2	60.9	27.0	37.7	35.7	−3	20
Engineering	**366.5**	**0**	**380.3**	**314.8**	**184.0**	**147.1**	**137.2**	**−4**	**22**
TOTAL	**$1966.9**	**11%**	**$1747.9**	**$1499.1**	**$1229.8**	**$1175.9**	**$1093.6**	**13%**	**12%**
ANNUAL CHANGE	**13%**	—	**17%**	**22%**	**5%**	**8%**	**13%**		

Note: Data for institutional fiscal years. Includes expenditures for facilities and equipment for research, development, and instruction. **Source:** National Science Foundation

UNIVERSITY SPENDING FOR RESEARCH EQUIPMENT: Hefty increase for chemistry in 1988

	1988		1987		1981		Annual change			
							1987–88		1981–88	
$ Millions	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds
All sciences	**$668.9**	**$414.4**	**$604.4**	**$378.6**	**$336.9**	**$213.7**	11%	10%	10%	10%
Life sciences	**384.2**	**213.2**	**334.7**	**187.1**	**194.9**	**117.4**	**15**	**14**	**10**	**9**
Physical sciences	**180.3**	**141.6**	**164.6**	**129.7**	**77.1**	**59.3**	**10**	**9**	**13**	**13**
Physics	84.4	67.2	79.9	66.0	32.8	26.7	6	2	14	14
Chemistry	74.4	57.6	65.6	48.6	35.3	25.6	13	19	11	12
Environmental sciences	**55.7**	**36.8**	**56.0**	**36.4**	**31.1**	**18.9**	**−1**	**1**	**9**	**10**
Mathematical and computer sciences	**54.1**	**42.2**	**52.5**	**41.5**	**15.1**	**9.0**	**3**	**2**	**20**	**25**
Other sciences	**48.6**	**22.9**	**49.0**	**25.5**	**20.9**	**11.7**	**−1**	**−10**	**13**	**10**
Engineering	**195.7**	**118.0**	**178.7**	**105.4**	**72.7**	**45.1**	**10**	**12**	**15**	**15**
Chemical	14.9	8.0	14.3	7.5	7.0	4.4	5	6	11	9
TOTAL	**$918.7**	**$574.6**	**$835.6**	**$525.6**	**$411.7**	**$261.3**	10%	9%	12%	12%

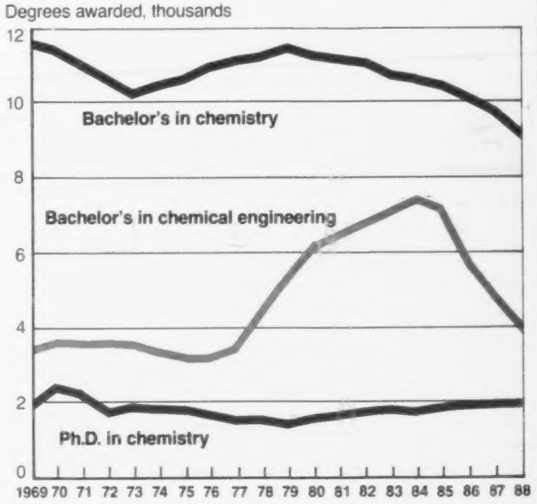
Note: Data for institutional fiscal years. **Source:** National Science Foundation

CHEMICAL DEGREES: Only increases during past decade are at Ph.D. level

Academic year	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1969	11,807	2070	1941	3557	1136	409
1970	11,617	2146	2208	3720	1045	438
1971	11,183	2284	2160	3615	1100	406
1972	10,721	2259	1971	3663	1154	394
1973	10,226	2230	1882	3636	1051	397
1974	10,525	2138	1828	3454	1045	400
1975	10,649	2006	1824	3142	990	346
1976	11,107	1796	1623	3203	1031	308
1977	11,322	1775	1571	3581	1086	291
1978	11,474	1892	1525	4615	1237	259
1979	11,643	1765	1518	5655	1149	304
1980	11,446	1733	1551	6383	1271	284
1981	11,347	1654	1622	6527	1267	300
1982	11,062	1751	1722	6740	1285	311
1983	10,746	1604	1746	7145	1304	319
1984	10,704	1667	1744	7475	1514	330
1985	10,482	1719	1789	7146	1544	418
1986	10,116	1754	1908	5877	1361	446
1987	9,661	1738	1976	4983	1184	497
1988	9,025	1694	1990	3926	1103	579

Source: National Center for Education Statistics

Bachelor's degrees continue to drop



Note: Academic years. **Source:** National Center for Education Statistics

TOP 10 UNIVERSITIES IN R&D SPENDING: Four universities vie for second place

$ Millions, fiscal 1987	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math & computer sciences	Other sciences	Total
1 **Johns Hopkins U**	$ 96.7	$ 5.2	$ 162.4	$ 33.0	$ 156.6	$ 90.3	$ 18.0	**$ 557.0**
2 **Stanford U**	56.6	10.5	75.8	4.5	117.8	16.5	6.3	**277.5**
3 **Cornell U**	42.5	10.5	39.8	7.0	149.5	19.5	13.4	**271.7**
4 **U of Wisconsin, Madison**	25.6	7.3	32.3	20.6	156.0	6.8	30.1	**271.4**
5 **Massachusetts Institute of Technology**	84.6	13.3	107.3	11.7	34.8	12.5	19.7	**270.6**
6 **U of Minnesota**	12.6	5.2	25.5	6.3	186.3	5.7	15.7	**252.0**
7 **U of Michigan**	15.7	3.9	42.8	14.6	132.0	3.0	42.0	**250.2**
8 **Texas A&M U**	15.2	8.8	37.5	56.2	101.2	3.2	17.7	**231.2**
9 **U of California, Los Angeles**	20.8	9.5	21.5	11.3	125.4	6.8	23.6	**209.3**
10 **U of California, San Diego**	25.1	6.8	4.5	70.2	89.8	7.1	3.8	**200.5**
TOTAL, FIRST 10 INSTITUTIONS	**$ 395.5**	**$ 81.0**	**$ 549.4**	**$235.3**	**$1249.2**	**$171.5**	**$ 190.4**	**$ 2,791.3**
TOTAL, ALL INSTITUTIONS	**$1531.6**	**$565.6**	**$2083.7**	**$890.9**	**$7236.1**	**$608.4**	**$1071.4**	**$13,422.1**

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal 1988 comparisons with data reported in earlier years may be inappropriate in some areas. a Included in physical sciences. **Source:** National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL R&D: Ten spent almost one fifth of total in 1988

Rank			1988		1987	1986	1985	1984	1983	Annual change	
1988	1987		Total spending ($ thousands)	% federal funds	($ thousands)					1987–88	1983–88
1	1	**U of California, Berkeley**	$ 14,285	91%	$ 12,490	$ 9,114	$ 10,804	$ 7,850	$ 7,945	14%	12%
2	2	**Massachusetts Inst. of Technology**	13,287	90	11,471	13,593	13,221	11,741	8,914	16	8
3	3	**U of Texas, Austin**	10,943	59	11,420	8,531	7,908	6,639	5,938	−4	13
4	8	**Stanford University**	10,547	89	8,916	8,340	8,354	6,809	6,375	18	11
5	10	**Cornell U**	10,472	79	8,397	7,376	7,962	6,710	5,717[a]	25	13
6	4	**California Inst. of Technology**	9,931	88	10,870	9,176	7,605	6,446	6,994	−9	7
7	9	**Harvard U**	9,886	94	8,895	7,202	6,557[a]	6,307[a]	6,898[a]	11	7
8	5	**U of California, Los Angeles**	9,519	93	10,099	7,954	7,243	7,219	5,496	−6	12
9	13	**Texas A&M U**	8,785	56	7,462	7,230[a]	6,768[a]	5,606[a]	4,963	17	12
10	7	**U of Illinois, Urbana**	8,647	72	9,035	8,604	7,079	6,284	5,886	−4	8
		Total, first 10 institutions	$106,302	82%	$ 99,055	$ 87,120	$ 83,501	$ 71,611	$ 65,126	7%	10%
11	15	**Purdue U**	8,615	83	7,092	6,315	6,018	5,443	4,542	21	14
12	6	**U of Maryland, College Park**	8,545	44	9,258	7,904	7,289	6,324	6,333[a]	−7	6
13	20	**Princeton U**	8,087	72	6,477	5,702	3,963	3,670	3,509	25	18
14	12	**U of Chicago**	8,046	90	7,514	7,553[a]	6,921[a]	5,735	4,798	7	11
15	14	**Case Western Reserve U**	7,996	68	7,164	2,922[a]	2,802	2,759	2,232	12	29
16	21	**Indiana U**	7,991	80	6,181	6,110	5,820	5,642	5,551	29	8
17	23	**Pennsylvania State U**	7,739	77	6,072	6,438	6,509	5,124	4,729	27	10
18	24	**Ohio State U**	7,568	72	5,755	6,546	5,422	4,104	3,739	32	15
19	18	**U of Pennsylvania**	7,292	87	6,741	6,064	5,025	4,375	4,982	8	8
20	16	**U of Wisconsin, Madison**	7,282	68	6,984	7,892	7,350	6,076	5,310	4	7
		Total, first 20 institutions	$185,463	79%	$168,293	$150,566	$140,620	$120,863	$110,851	10%	11%
21	27	**U of Notre Dame**	7,004	94	5,550	5,402	5,549	4,760	4,022	26	12
22	17	**Rockefeller U**	6,975	44	6,823	7,335	4,826[a]	1,178	919	2	50
23	19	**Columbia U, main division**	6,931	94	6,715	5,555	5,188	4,662	4,281	3	10
24	28	**Yale U**	6,869	86	5,538	6,169[a]	5,600[a]	4,134	3,341	28	16
25	30	**U of California, San Diego**	6,780	91	5,179	6,535	4,642	4,355	3,910	31	12
26	22	**Northwestern U**	6,644	75	6,095	4,826	5,062	4,557	3,413	9	14
27	33	**Georgia Inst. of Technology**	5,989	60	4,889	5,260	3,684	3,846	3,401	23	12
28	42	**Rutgers U**	5,926	58	3,913	3,507	2,368	2,301	1,830	51	26
29	31	**U of Colorado**	5,637	82	5,118	5,830	6,360	4,134	3,302	10	11
30	32	**U of Pittsburgh**	5,598	86	5,105	4,974	4,580	3,965	3,267	10	11
		Total, first 30 institutions	$249,816	78%	$223,218	$205,959	$188,479	$158,755	$142,537	12%	12%
31	36	**U of Oregon, main campus**	5,550	81	4,462	5,087	4,640	4,255	3,351	24	11
32	11	**U of Massachusetts, Amherst**	5,280	62	7,589	6,967	6,420	6,347	5,162	−30	0
33	29	**U of Minnesota**	5,239	79	5,426	5,110	4,167	4,067	4,047	−3	5
34	26	**Johns Hopkins U**	5,211	93	5,593	5,506	4,652[a]	4,030	4,592[a]	−7	3
35	25	**U of Florida**	5,030	63	5,690	4,750	4,380	4,024	2,347	−12	16
36	48	**State U of New York, Stony Brook**	5,010	69	3,669	3,333	3,481	3,084	2,607	37	14
37	46	**Colorado State U**	4,950	86	3,713	3,867	2,775	2,688	2,478	33	15
38	38	**Virginia Polytechnic Inst. & State U**	4,735	51	4,190	3,786	3,417	2,686	2,206	13	17
39	34	**U of Utah**	4,600	79	4,846	5,354	4,840	3,830	3,638	−5	5
40	60	**Wayne State U**	4,582	47	3,278	3,405	2,903	3,071	2,645	40	12
		Total, first 40 institutions	$300,003	77%	$271,674	$253,124	$230,154	$196,837	$175,610	10%	11%
41	53	**U of California, Irvine**	4,534	97	3,541	3,486	3,142	2,177	1,777	28	21
42	37	**Lehigh U**	4,510	43	4,410	4,237	3,456	3,361	3,664	2	4
43	54	**U of North Carolina, Chapel Hill**	4,476	94	3,471	3,352	3,386	2,945	2,397	29	13
44	52	**U of Rochester**	4,437	89	3,545	3,584	3,196	3,858	3,167	25	7
45	49	**U of Washington**	4,338	67	3,655	2,971	2,964	2,340	2,162	19	15
46	44	**Florida State U**	4,308	33	3,841	4,047	3,276	3,137	2,500	12	11
47	57	**U of Connecticut**	4,279	26	3,396	3,380	3,429	4,135	2,720	26	9
48	39	**U of Virginia**	4,153	82	4,169	3,436	3,046	2,516	2,069	0	15
49	35	**U of South Carolina**	4,078	70	4,622	4,432	3,850	3,423	2,721	−12	8
50	45	**U of Cincinnati**	4,008	52	3,816	1,684	1,593	1,633	1,217	5	27
		Total, first 50 institutions	$343,124	76%	$310,140	$287,733	$261,492	$226,362	$200,034	11%	11%
		NATIONAL TOTAL	$565,637	71%	$509,512	$468,778	$421,506	$369,945	$334,663	11%	11%

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal year 1988 comparisons with data reported in earlier years may be inappropriate in some areas. Data since 1985 were revised in 1988. a Estimated. **Source:** National Science Foundation

SCHOOLS WITH MOST FEDERAL SUPPORT FOR CHEMICAL R&D: Two get over $10 million each

Rank			1988	1987	1986	1985	1984	1983	Annual change	
1988	1987		($ thousands)						1987–88	1983–88
1	1	**U of California, Berkeley**	$ 12,998	$ 11,160	$ 8,258	$ 9,892	$ 7,263	$ 7,467	16%	12%
2	2	**Massachusetts Inst. of Technology**	11,987	10,656	12,909	12,424	11,055	8,374	12	7
3	6	**Stanford U**	9,423	7,918	7,524	7,097	6,120	5,968	19	10
4	5	**Harvard U**	9,272	8,309	6,748	6,557	6,307	5,224	12	12
5	4	**U of California, Los Angeles**	8,885	9,414	7,516	6,719	6,389	5,047	−6	12
6	3	**California Inst. of Technology**	8,769	9,922	7,612	7,001	5,810	6,554	−12	6
7	7	**Cornell U**	8,269	6,753	5,934	6,293	5,775	4,766	22	12
8	9	**U of Chicago**	7,235	6,499	6,769[a]	6,265[a]	5,116	3,998	11	13
9	12	**Purdue U**	7,120	5,978	5,708	5,418	4,452	3,966	19	12
10	14	**U of Notre Dame**	6,557	5,158	4,998	5,097	4,416	3,867	27	11
		Total, first 10 institutions	$ 90,515	$ 81,767	$ 73,976	$ 72,763	$ 62,703	$ 55,231	11%	10%
11	8	**Columbia U, main division**	6,519	6,625	5,030	4,490	4,639	4,279	−2	9
12	10	**U of Texas, Austin**	6,443	6,405	4,922	4,741	3,873	3,527	1	13
13	19	**Indiana U**	6,354	4,923	4,757	4,885	4,694	4,642	29	6
14	13	**U of Pennsylvania**	6,337	5,653	5,232	4,398	3,921	4,037	12	9
15	11	**U of Illinois, Urbana**	6,193	6,306	5,999	5,371	5,005	4,668	−2	6
16	24	**U of California, San Diego**	6,161	4,599	5,918	4,053	3,780	3,490	34	12
17	20	**Pennsylvania State U**	5,957	4,915	5,161	5,860	4,564	4,236	21	7
18	21	**Yale U**	5,927	4,909	5,566[a]	5,095[a]	3,528	3,008	21	15
19	16	**Princeton**	5,812	5,064	4,575	3,104	2,892	2,642	15	17
20	25	**Ohio State U**	5,437	4,517	4,931	3,846	2,904	2,870	20	14
		Total, first 20 institutions	$151,655	$135,683	$126,067	$118,606	$102,503	$ 92,630	12%	10%
21	18	**Case Western Reserve U**	5,433	5,016	2,062	2,065	1,904	1,443	8	30
22	23	**Northwestern U**	4,955	4,641	3,753	3,963	3,471	3,012	7	10
23	31	**Texas A&M U**	4,945	4,019	3,128	4,195	2,735	3,327	23	8
24	22	**U of Wisconsin, Madison**	4,939	4,718	5,348	5,156	4,391	3,693	5	6
25	15	**Johns Hopkins U**	4,830	5,116	4,903	4,155	3,783	3,604[a]	−6	6
26	30	**U of Pittsburgh**	4,803	4,028	4,045	3,836	3,343	2,833	19	11
27	26	**U of Colorado**	4,603	4,402	4,911	5,430	3,358	2,695	5	11
28	32	**U of Oregon**	4,519	3,579	4,345	3,959	3,524	2,686	26	11
29	35	**U of California, Irvine**	4,376	3,386	3,394	3,035	2,096	1,725	29	20
30	38	**Colorado State U**	4,280	3,273	3,403	2,434	2,426	2,055	31	16
		Total, first 30 institutions	$199,338	$177,861	$165,359	$156,834	$133,534	$119,703	12%	11%
31	40	**U of North Carolina, Chapel Hill**	4,193	3,153	2,929	2,885	2,699	2,381	33	12
32	27	**U of Minnesota**	4,156	4,395	4,013	3,295	3,346	3,345	−5	4
33	37	**U of Rochester**	3,936	3,275	3,336	2,861	3,490	2,800	20	7
34	29	**U of Maryland, College Park**	3,793	4,073	3,557	3,323	2,862	2,834	−7	6
35	28	**U of Utah**	3,614	4,194	4,791	4,426	3,380	3,085	−14	3
36	45	**Georgia Inst. of Technology**	3,574	2,565	2,914	2,051	2,227	2,032	39	12
37	42	**U of Southern California**	3,568	2,903	2,857	2,149	2,495	2,456	23	8
38	43	**State U of New York, Stony Brook**	3,460	2,930	2,168[a]	2,343	2,069	1,809	18	14
39	46	**Rutgers U**	3,442	2,525	2,123	2,055	2,129	1,740	36	15
40	36	**U of Virginia**	3,419	3,281	2,748	2,165	2,099	1,663	4	16
		Total, first 40 institutions	$236,493	$211,155	$196,795	$184,387	$160,330	$143,848	12%	10%
41	44	**U of Michigan**	3,310	2,615	2,367	2,286	2,356	1,853	27	12
42	17	**U of Massachusetts, Amherst**	3,296	5,036	4,411	4,091	3,887	3,336	−35	0
43	33	**U of California, Santa Barbara**	3,196	3,526	3,087	2,709	1,881	1,723	−9	13
44	34	**U of Florida**	3,168	3,486	2,729	2,302	2,042	1,325	−9	19
45	39	**Rockefeller U**	3,082	3,247	3,377	2,553	833	584	−5	39
46	60	**Carnegie Mellon U**	3,001	2,055	1,494	1,569	1,505	1,497	46	15
47	54	**U of Washington**	2,904	2,287	1,898	2,016	1,919	1,771	27	10
48	48	**U of Arizona**	2,885	2,499	2,291	1,738	1,843	1,557	15	13
49	63	**U of California, Riverside**	2,844	1,881	2,108	1,252	1,951	1,343	51	16
50	41	**U of South Carolina**	2,839	3,113	3,285	2,787	2,533	2,221	−9	5
		Total, first 50 institutions	$267,018	$240,900	$223,842	$207,690	$183,436	$161,058	11%	11%
		NATIONAL TOTAL	$403,018	$365,244	$337,735	$312,831	$278,215	$247,652	10%	10%

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal year 1988 comparisons with data reported in earlier years may be inappropriate in some areas. Data since 1985 were revised in 1988. **a** Estimated. **Source:** National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL ENGINEERING R&D: Federal funds provide half of total

Rank 1988	Rank 1987		Chemical engineering: Total spending ($ thousands)	Chemical engineering: Federal funds	Chemical engineering: % federal funds	All engineering: Total spending ($ thousands)	All engineering: Federal funds	All engineering: % federal funds
1	1	**Massachusetts Inst. of Technology**	$ 9,252	$ 6,119	66%	$ 107,281	$ 77,811	73%
2	2	**U of Minnesota**	6,506	3,647	56	25,498	8,890	35
3	3	**U of Texas, Austin**	4,315	1,662	39	46,086	21,150	46
4	10	**Texas A&M U**	4,232	875	21	37,517	11,441	31
5	8	**U of Maryland, College Park**	3,681	1,238	34	37,807	15,397	41
6	5	**Johns Hopkins U**	3,654	3,385[a]	92	162,390	159,976	99
7	7	**North Carolina State U, Raleigh**	3,572	1,036	29	31,219	9,823	31
8	11	**Stanford U**	3,506	2,954	84	75,828	63,486	84
9	6	**U of Wisconsin, Madison**	3,351	1,952	58	32,287	21,125	65
10	9	**Brigham Young U**	3,157	2,704	86	5,308	3,819	72
		Total, first 10 institutions	**$ 45,226**	**$25,572**	**57%**	**$ 561,221**	**$ 392,918**	**70%**
11	18	**Case Western Reserve U**	2,925	1,662	57	16,062	10,911	68
12	13	**U of Delaware**	2,673	821	31	9,596	4,025	42
13	16	**U of Michigan**	2,637	1,866	71	42,808	24,633	58
14	17	**Columbia U, main division**	2,609	666	26	15,677	12,747	81
15	21	**Pennsylvania State U**	2,399	921	38	82,807	54,583	66
16	22	**Cornell U**	2,388	1,245	52	39,822	24,232	61
17	14	**U of Pennsylvania**	2,380	1,966	83	8,878	5,743	65
18	23	**Princeton U**	2,335	1,054	45	17,964	10,521	59
19	12	**Lehigh U**	2,243	654	29	18,949	6,449	34
20	15	**Georgia Inst. of Technology**	2,142	1,278	60	88,315	52,700	60
		Total, first 20 institutions	**$ 69,957**	**$37,705**	**54%**	**$ 902,099**	**$ 599,462**	**66%**
21	25	**Purdue U**	2,073	1,174	57	32,206	19,612	61
22	34	**U of California, Los Angeles**	2,011	1,534	76	21,497	15,733	73
23	24	**California Inst. of Technology**	2,001	1,825	91	17,407	14,798	86
24	29	**Auburn U**	1,928	899	47	15,775	9,124	58
25	20	**U of Washington**	1,911	1,014	53	16,374	11,296	69
26	28	**U of Houston**	1,882	815	43	6,725	2,999	45
27	31	**U of California, Santa Barbara**	1,845	1,645	89	13,461	11,178	83
28	26	**U of California, Berkeley**	1,774	1,129	64	42,432	25,371	60
29	4	**New Mexico Inst. of Mining & Tech.**	1,712	308	18	15,114	3,874	26
30	37	**Carnegie Mellon U**	1,637	1,267	77	25,548	14,005	55
		Total, first 30 institutions	**$ 88,731**	**$49,315**	**56%**	**$1,108,638**	**$ 727,452**	**66%**
		NATIONAL TOTAL	**$154,392**	**$79,153**	**51%**	**$2,083,745**	**$1,224,617**	**59%**

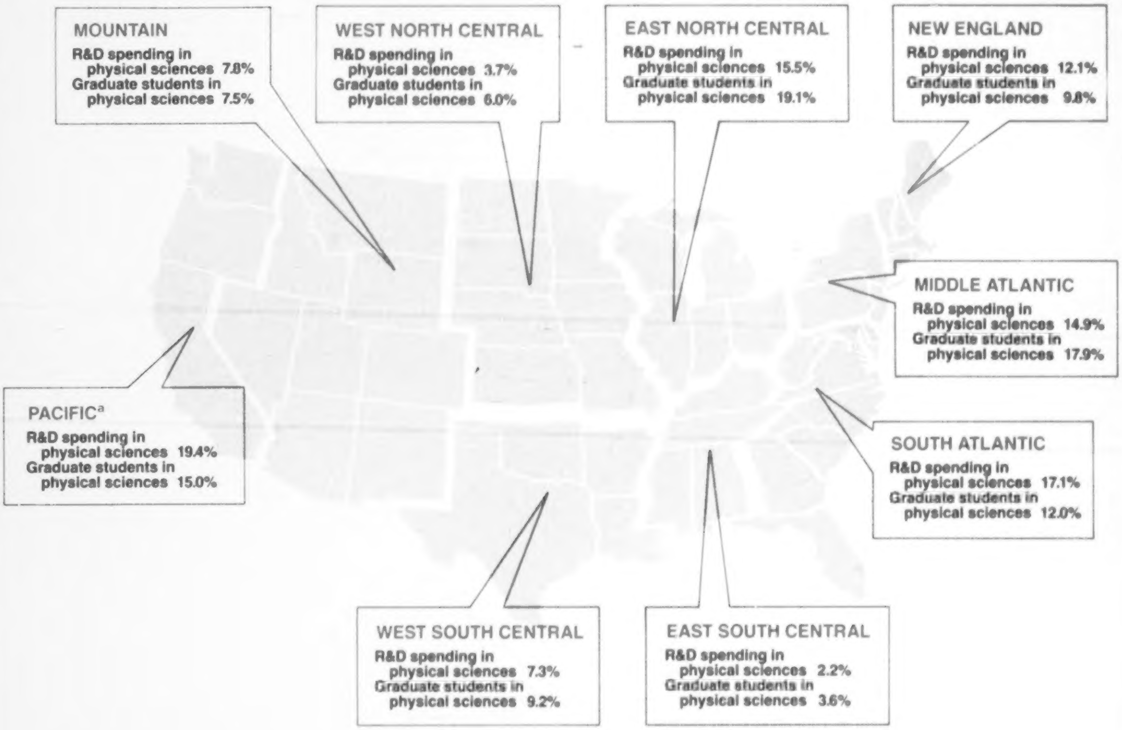
Note: Data for fiscal 1988. a Estimated. **Source:** National Science Foundation

FOREIGN GRADUATE STUDENTS: They now represent almost a third of total

	1988		1987		1986		1985		1984		1983		Annual change	
	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	1987–88	1983–88
All sciences	**49.3**	**27%**	**46.2**	**26%**	**43.7**	**25%**	**40.0**	**23%**	**36.4**	**21%**	**35.2**	**20%**	**7%**	**6%**
Psychology and social sciences	13.9	20	13.1	18	12.7	18	12.1	18	11.1	16	11.2	16	6	4
Mathematical and computer sciences	11.6	44	11.0	42	10.4	41	9.5	41	8.3	40	7.6	39	6	10
Biological sciences	8.9	23	7.9	21	7.0	19	6.2	17	5.6	16	5.3	15	12	11
Biochemistry	1.3	28	1.2	26	1.1	23	1.0	22	0.8	20	0.8	19	9	11
Physical sciences	10.2	37	9.8	35	9.3	34	8.3	32	7.4	30	7.0	29	4	8
Chemistry	5.2	33	4.8	31	4.4	28	4.0	26	3.5	24	3.4	23	8	9
Physics	4.8	43	4.8	43	4.7	44	4.1	41	3.8	38	3.5	38	1	7
Agricultural sciences	2.5	29	2.5	30	2.5	28	2.3	26	2.3	25	2.4	25	0	1
Environmental sciences	2.1	21	1.9	19	1.8	16	1.6	15	1.6	14	1.7	14	12	5
Engineering	**28.4**	**46**	**27.4**	**45**	**26.4**	**45**	**23.5**	**43**	**22.6**	**42**	**22.2**	**42**	**4**	**5**
Chemical	2.4	44	2.3	41	2.2	39	2.2	40	2.1	37	2.2	38	3	1
Metallurgical and materials	1.6	47	1.6	47	1.5	45	1.3	42	1.2	42	1.2	43	2	7
TOTAL	**77.7**	**32%**	**73.7**	**31%**	**70.1**	**30**	**63.5**	**28**	**59.0**	**26**	**57.5**	**26**	**5%**	**6%**
ANNUAL CHANGE	**5.4%**		**5.1%**		**10.3%**		**7.6%**		**2.6%**		**8.1%**			

Note: Data are for full-time graduate students at Ph.D-granting institutions only. The percent of total is the percent of all full-time graduates in each area who are foreign. **Source:** National Science Foundation

R&D funding and graduate students in physical sciences are highest in East and Far West


MOUNTAIN
R&D spending in physical sciences 7.8%
Graduate students in physical sciences 7.5%
WEST NORTH CENTRAL
R&D spending in physical sciences 3.7%
Graduate students in physical sciences 6.0%
EAST NORTH CENTRAL
R&D spending in physical sciences 15.5%
Graduate students in physical sciences 19.1%
NEW ENGLAND
R&D spending in physical sciences 12.1%
Graduate students in physical sciences 9.8%
MIDDLE ATLANTIC
R&D spending in physical sciences 14.9%
Graduate students in physical sciences 17.9%
PACIFIC[a]
R&D spending in physical sciences 19.4%
Graduate students in physical sciences 15.0%
SOUTH ATLANTIC
R&D spending in physical sciences 17.1%
Graduate students in physical sciences 12.0%
WEST SOUTH CENTRAL
R&D spending in physical sciences 7.3%
Graduate students in physical sciences 9.2%
EAST SOUTH CENTRAL
R&D spending in physical sciences 2.2%
Graduate students in physical sciences 3.6%

Key to map: Using the Middle Atlantic states as an example, 14.9% of all R&D expenditures in the physical sciences and 17.9% of all graduate students in physical sciences are in this area. The figures for funding apply to Ph.D.-granting universities and colleges only. The figures for students apply to all universities and colleges.

Note: Data are based on $1.5 billion of R&D expenditures and 33,047 graduate students in the physical sciences enrolled in colleges and universities during the 1988 fiscal year. **a** Includes Alaska, Hawaii, and outlying areas. **Source:** National Science Foundation

GRADUATE SCIENCE STUDENTS: Number in chemistry falls for first time in more than a decade

												Annual change	
Thousands	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1987–88	1978–88
All sciences	250.6	246.2	242.6	238.0	233.4	232.5	231.4	228.0	227.1	219.8	213.9	2%	2%
Psychology and social sciences	107.6	105.6	103.1	102.2	102.0	104.2	107.3	108.7	109.7	105.8	101.2	2	9
Biological sciences	44.7	43.6	43.4	42.5	41.9	41.6	41.9	42.0	42.7	42.6	43.1	2	0
Biochemistry	4.9	4.8	4.9	4.7	4.5	4.2	4.1	4.0	4.0	3.9	4.0	3	2
Mathematical and computer sciences	43.8	42.3	40.9	39.1	35.4	33.2	30.3	27.1	25.0	22.7	21.5	4	7
Physical sciences	31.3	31.0	30.5	29.3	28.4	27.7	26.5	25.8	25.4	24.9	24.7	1	2
Chemistry	17.5	17.7	17.6	17.2	16.6	16.5	15.8	15.2	15.1	14.9	14.8	−1	2
Physics	12.8	12.3	12.0	11.3	11.0	10.5	10.0	9.9	9.6	9.3	9.2	4	3
Environmental sciences	13.0	13.4	14.1	14.3	14.3	14.3	13.8	13.1	12.8	12.6	12.2	−3	1
Agricultural sciences	10.3	10.3	10.7	10.7	11.3	11.5	11.6	11.3	11.6	11.3	11.1	0	−1
Engineering	97.0	97.0	95.8	90.2	87.1	85.3	78.2	74.4	70.1	67.2	64.3	0	4
Chemical	6.5	7.0	6.9	7.0	7.2	7.4	6.9	6.3	5.9	5.4	5.2	−7	2
Metallurgical and materials	4.2	4.2	4.0	3.8	3.6	3.3	3.0	3.0	2.8	2.7	2.5	−1	5
Petroleum	0.7	0.8	0.7	0.8	0.7	0.7	0.6	0.5	0.5	0.4	0.4	−10	6
TOTAL	347.5	343.2	338.3	328.3	320.5	317.9	309.5	302.4	297.3	287.0	278.1	1	2
ANNUAL CHANGE	1%	1%	3%	2%	1%	3%	2%	2%	4%	3%	1%		

Note: Data for Ph.D-granting institutions only. **Source:** National Science Foundation

5 R&D International

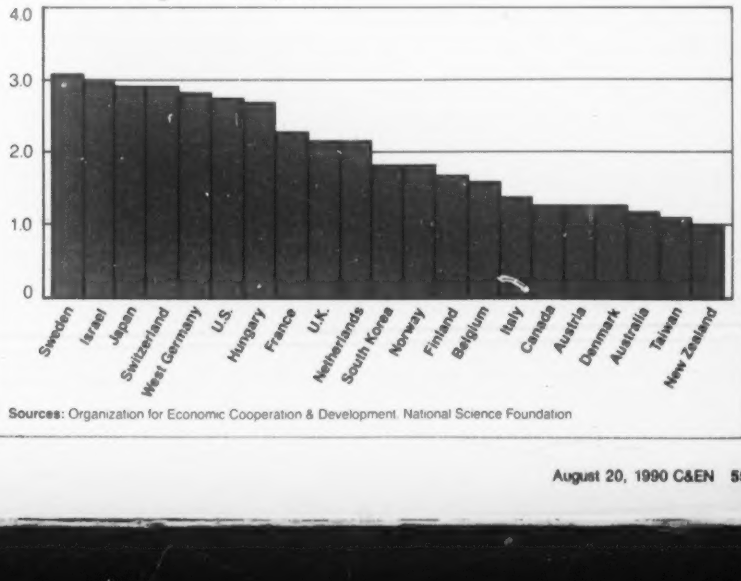
U.S. Lead in Worldwide R&D Slipping

WORLDWIDE R&D SCIENTISTS AND ENGINEERS: **Strong upturn for Japan in 1988**

Thousands	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
U.S.	949	923	897	849	798	752	711	683	651	615	587	3%	5%
Japan	462	418	406	381	370	342	330	318	303	282	273	11	5
West Germany	na	166[a]	156[a]	148	137[a]	131	128[a]	125	121[a]	117	114	6[b]	—
France	na	109[a]	105[a]	102	98	93	90	86	75	73	71	4[b]	—
U.K.	na	101	102	98	96[a]	94	na	96	na	na	88	−1[b]	—
Per 10,000 in labor force													
U.S.	na	75.9	75.0	72.5	69.2	66.4	63.6	61.9	60.0	57.7	56.5	—	—
Japan	na	68.8	67.4	63.9	62.4	58.1	57.1	55.6	53.6	50.4	49.4	—	—
West Germany	na	58.7	52.3[a]	51.6	49.6[a]	47.4	46.4[a]	45.5	44.3[a]	43.4	42.7[a]	—	—
France	na	44.9	43.8[a]	42.8	41.1	39.1	37.9	36.3	32.1	31.4	30.7	—	—
U.K.	na	35.9	35.5	35.5	35.5[a]	35.4	na	35.8	na	na	33.3	—	—

Note: Table represents all scientists and engineers engaged in R&D on a full-time equivalent basis except Japan, whose data include persons primarily employed in R&D in the natural sciences and engineering, and all higher education natural science and engineering faculty. The U.K. data include only the government and industry sectors. The figures for West Germany increased in 1979 partially because of increased coverage of small and medium-size enterprises not surveyed in 1977. The data for France increased in 1981 in part due to a reevaluation of university research efforts. **na** = not available. a Estimated. b Annual change for 1986–87. **Source:** National Science Foundation

Five countries spend more of GNP on R&D than U.S.



Sources: Organization for Economic Cooperation & Development, National Science Foundation

WORLDWIDE R&D EXPENDITURES: U.S. spends more than double its nearest competitor

$ Millions, constant 1982		% of GNP	$ Millions, constant 1982		% of GNP	$ Millions, constant 1982		% of GNP
U.S. (1988)	$111,503	2.8%	**Switzerland** (1986)	$2516	2.9%	**Norway** (1987)	$1006	1.8%
Japan (1988)	42,314	2.9	**South Korea** (1987)	1945	1.8	**Yugoslavia** (1987)	976	0.8
West Germany (1988)	20,068	2.8	**Australia** (1986)	1921	1.2	**Finland** (1988)	911	1.7
France (1988)	14,591	2.3	**India** (1986)	1858	0.9	**Mexico** (1984)	881	0.6
U.K. (1986)	13,742	2.2	**Belgium** (1986)	1616	1.6	**Denmark** (1985)	707	1.3
Italy (1988)	7,918	1.4	**Spain** (1986)	1547	0.6	**Israel** (1983)	637	3.0
Canada (1988)	5,300	1.3	**Brazil** (1985)	1448	0.7	**Hungary** (1987)	588	2.7
Netherlands (1986)	3,341	2.2	**Argentina** (1981)	1087	0.4	**Taiwan** (1985)	505	1.1
Sweden (1987)	2,901	3.1	**Austria** (1988)	1034	1.3	**New Zealand** (1987)	246	1.0

Note: Data are for the most current year available (in parentheses). Countries differ in statistical collection capabilities and definitions. In addition, some R&D/gross national product percentages are R&D/gross domestic product. Foreign currency conversions to U.S. dollars were calculated with Organization for Economic Cooperation & Development purchasing power parities or using International Monetary Fund average-for-period par/market exchange rates. **Source:** National Science Foundation

TOTAL AND NONDEFENSE R&D: Japan's R&D spending is rising much faster than U.S.'s

												Annual change	
$ Billions, constant 1982	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1987–88	1978–88
TOTAL R&D													
U.S.[a]	$111.5	$108.4	$105.3	$102.6	$93.9	$85.8	$80.0	$76.4	$73.0	$69.9	$66.7	3%	5%
Japan	42.3	39.2	36.6	36.1	32.4	29.9	27.4	25.5	23.1	21.0	19.1	8	8
West Germany	19.4	19.4	18.6	18.5	16.9	16.4	16.3	15.9	15.3	15.0	13.3	0	4
France	14.6	14.0	13.6	13.1	12.6	11.9	11.5	10.8	9.8	9.4	8.9	4	5
U.K.	13.8	13.8	13.6	12.8	na	11.9	na	12.2	na	na	11.1	0	2
NONDEFENSE R&D													
U.S.[a]	$ 80.3	$ 78.0	$ 73.7	$ 71.8	$66.7	$61.8	$58.4	$57.3	$54.8	$51.7	$48.7	3%	5%
Japan	42.0	38.9	36.4	35.9	32.4	29.9	27.5	25.7	23.3	21.1	19.1	8	8
West Germany	19.1	18.5	17.4	17.1	16.2	15.3	15.8	15.2	14.5	14.2	12.5	3	4
France	11.3	11.0	10.7	10.5	9.9	9.4	9.1	8.1	7.6	7.4	7.2	3	5
U.K.	10.5	10.3	10.2	9.1	na	8.5	na	8.7	na	na	8.0	2	3

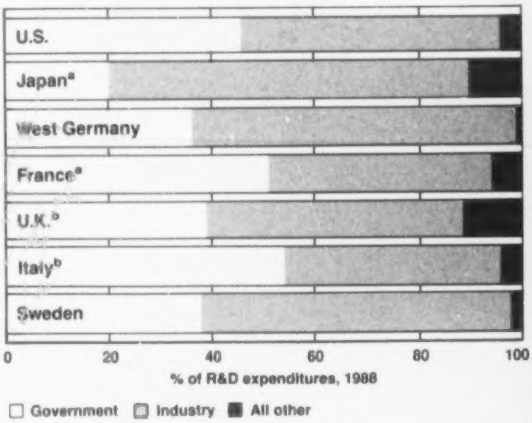
Note: Foreign currency conversions to U.S. dollars are calculated based on Organization for Economic Cooperation & Development purchasing power parity exchange rates. a C&EN estimates based on NSF data. na = not available. **Source:** National Science Foundation

ORIGIN OF CHEMICAL LITERATURE: Half comes from U.S., U.S.S.R., and Japan

% of total[a]	1989	1985	1981	1977	1973
U.S.	27.8%	27.0%	27.4%	25.6%	26.4%
U.S.S.R.	12.7	14.9	16.6	23.2	24.7
Japan	11.8	11.3	10.5	8.2	7.5
West Germany	6.2	6.2	6.0	6.0	5.3
U.K.	5.7	5.8	6.1	6.2	6.0
France	4.2	4.3	4.2	4.2	4.3
China	3.7	2.6	1.4	0.1	0.0
Canada	3.0	2.9	2.6	2.7	2.8
India	2.8	3.0	3.3	3.0	2.6
Italy	2.3	2.4	2.2	1.9	1.9
Poland	1.6	1.7	2.1	2.1	2.0
Netherlands	1.5	1.4	1.3	1.2	1.1
Spain	1.4	1.2	0.7	0.6	0.4
Australia	1.2	1.4	1.4	1.2	1.1
East Germany	1.2	1.2	1.3	1.2	1.1
Sweden	1.2	1.2	1.1	1.1	1.1
Czechoslovakia	1.1	1.1	1.3	1.4	1.7
Switzerland	1.1	1.1	1.1	1.0	0.9
All others	9.5	9.3	9.4	9.1	9.3
TOTAL PAPERS (THOUSANDS)	397.2	380.1	374.0	348.1	269.7

a Source of journal literature abstracted in *Chemical Abstracts* based on author's address.
Source: Chemical Abstracts Service

Government's share of R&D funding is greatest in France and Italy



a Estimated. b Data are for 1987. **Sources:** Organization for Economic Cooperation & Development, National Science Foundation, individual nations

SEPTEMBER 3, 1990

EMICAL NEERING

NEWS

Erich Bloch

Retirement leaves
powerful legacy at NSF
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CHEMICAL & ENGINEERING
NEWS

Volume 68, Number 36
CENEAR 68 (36) 1–52
ISSN 0009-2347

SEPTEMBER 3, 1990

News of the Week

- **At ACS national meeting in Washington, D.C., top elected officials promise all-out fight against Dialog antitrust suit.** Page 4
- **OSHA begins new, rigorous petrochemical plant inspection program at large producers, in effort to prevent major catastrophic accidents.** Page 5
- **Some chemical firms are taking steps to aid families of employees called up for military reserve duty, including extending pay and benefits.** Page 5
- **Risk assessment and the public's understanding of risk highlighted at presidential plenary session at ACS national meeting.** Page 6
- **East European scientists outline help needed from West to upgrade their science and technology establishments.** Page 6
- **ACS's 200th national meeting in Washington, D.C., featured more than 4000 technical papers, hosted over 14,000.** Page 7
- **Progress reported on several fronts in effort to develop CFC alternatives.** Page 8

Cover: Photo by C&EN's Bette Hileman

Business

Fledgling biotech firm, Celgene, moves closer to market with a major patent and an experienced management team. **Page 14**

Demand for methanol is outpacing supply, largely because of the growing use of gasoline octane enhancer MTBE. **Page 17**

Government

EPA data on hazardous chemicals emissions are attracting more attention from citizen activist groups at state and local levels. **Page 23**

Science/Technology

Catalysis research promises new vitality to a maturing chemical industry. **Page 30**

National Cancer Institute to issue request for proposals for syntheses of potential anticancer agents. **Page 35**

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News Focus

Erich Bloch departs his position as director of NSF leaving mixed feelings among both staff and science community and a much-transformed agency in his wake. Page 9

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LETTERS

Chemical sensitivity

W. Alfred Mukatis (C&EN, June 4, page 3) characterizes chemical sensitivity as a serious problem and a debilitating illness in his letter. I agree with him, but not for the reasons he states.

"Chemical sensitivity" is a nonspecific illness that the sufferers claim is caused by an initial exposure to one or more chemicals, usually at work, resulting in an as-yet unspecified immune reaction to a variety of subsequent chemical stimuli. The claimants describe a number of vague symptoms that cannot be medically verified (transient loss of memory, numbness, unusual tastes, headache, for example). The sufferers seek treatment from a number of medical personnel, both traditional (MDs, RNs) and nontraditional (clinical ecologists, holistic healers). Nontraditional practitioners routinely prescribe a complete removal from the supposed noxious stimuli, often accompanied by vitamin, herbal, or homeopathic treatments.

In my professional experience, these cases share a number of features that make broad-spectrum chemical sensitivity a very unlikely case:

- The supposed stimulus almost always occurs at work, with a subsequent claim of work-related disability. As chemists we are aware, of course, that chemicals are ubiquitous in the universe, composing all of the materials we encounter in our daily lives (including our own bodies). It strains credibility to imagine that a class of "bad" chemicals found primarily in the workplace is responsible for an illness that can be treated with other "good" chemicals found only in nature (e.g., vitamins, herbal remedies).
- The chemicals claimed to be responsible for the initial "exposure" and the subsequent broad-spectrum sensitivity are almost always odorous organics. Frequent "offenders" are formaldehyde, paints, 4-phenylcyclohexene, gasoline and/or diesel fuels, acetone, and various common pesticides. It is highly suspect that these subjects do not complain of effects from materials that have no odors. Typically the claimant will experience an odor and attribute any subsequent feelings of ill-health to exposure to the odorous material. Naturally odoriferous materials similar in composition to the supposed causative agents (for example, complex pine resins or the scents of live flowers) rarely cause problems.
- The claimants share a distinctive psychological profile. They tend to be anxious, desperate personalities who have learned to use their ill health to manipulate others. Unfortunately, our society stigmatizes persons who admit to psychosocial illness; chemicals happen to be a convenient (and socially acceptable) scapegoat at present.

As I mentioned above, there is a movement (mostly promulgated by clinical ecologists) to legitimatize broad-spectrum chemical sensitivity as a compensable illness under workers' compensation. A great deal of social harm will result from blindly accepting this interpretation. In the majority of cases I have encountered, I believe the subjective symptoms claimed by "chemically sensitive" individuals are real (i.e., they really do feel bad and are not faking). Although I sympathize with the sufferers, I will be very surprised if a generalized immune response to "chemicals" is the cause of their problems. Any success that clinical ecologists have in treating these people is most likely explained by the placebo effects and/or removing most of the stress- and anxiety-producing aspects of the patients' lives, including conventional workplaces. Interested persons should read a recent review on this subject by Abba I. Terr, "Clinical Ecology in the Workplace," in the March 1989 *Journal of Occupational Medicine.*

Carol M. Rubin
Industrial Hygienist
Davis, Calif.

Student-adviser relationships

I am moved to write in support of David B. Morse's letter (C&EN, May 28, page 4) suggesting that negative attitudes among graduate students are largely a result of unhealthy student-adviser relationships.

Although my personal experience at graduate school has been very positive (which I attribute in part to careful selection of research adviser), I am routinely distressed by the inhumane treatment of some of my colleagues. The power of an adviser to influence a student's career is unfortunately often abused.

Abuse of graduate students by their advisers takes a variety of forms. Some students are expected to perform secretarial work. Others continually receive negative reinforcement from their advisers, who fail to take the time to teach them. I have seen some students manipulated by their advisers.

When I ask my colleagues why they put up with these injustices, they tell me they are afraid. They argue it is just for a few years and they can survive. However, a few years of mistreatment can lead to a lifetime of cynicism. I am most dis-

Growth in methanol supply lags demand

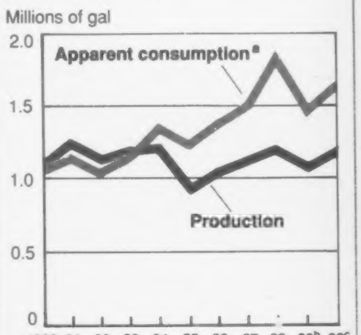
Worldwide methanol demand is rising faster than production capacity, resulting in improved operating rates. Continued improvement is forecast for the near future since few capacity expansions are scheduled for completion in the next three years. Spurring the growing demand is methyl *tert*-butyl ether, used in gasoline as an aid to lower exhaust pollutants.

A more than 10% increase forecast for methanol demand for MTBE in 1990 and a 21% increase in 1991 will result in plant operating rates in 1992 of about 85% of nameplate capacity, up from about 78% in 1989. Consumption of methanol in making formaldehyde, acetic acid, and other chemicals will grow much slower than its use in making MTBE.

Global demand for methanol will grow more than 18% between 1989 and 1992, but capacity will increase less than 9%, according to James J. Crocco, whose Houston-based consulting firm, Crocco & Associates, has released a new study on the international methanol situation. Counting this year's conversion of a plant in New Zealand from fuel-grade methanol to chemical grade, two small plants to be built in the U.S., and a world-scale plant in Saudi Arabia, capacity worldwide will reach more than 8 billion gal in 1992, Crocco says. Global demand is forecast to be 6.8 billion gal in 1992. MTBE demand for methanol will triple to 1.2 billion gal in 1992, up from 400 million gal in 1989, accounting for much of the methanol demand increase.

Plans to expand methanol capacity face financial limitations because of current low rates of return on methanol sales. U.S. spot prices for methanol are less than 30 cents per gal, with contract prices slightly above 30 cents and posted prices 37 to 40 cents per gal. Although influenced by shipping and storage costs, prices in other parts of the world are similar. In addition to return on investment, feedstock and energy costs are a large component of selling price. Consequently, most of the methanol expansions during the 1980s were located where natural gas costs were low. During the mid-

U.S. methanol consumption far outstrips production



a Production plus imports minus exports. **b** Preliminary. **c** Forecast. **Sources:** U.S. International Trade Commission, Department of Commerce, C&EN estimates

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1980s, several U.S. methanol plants were shut down because of low returns; in the late 1980s most were restarted.

Investment in new methanol facilities will only be made when the rising utilization rates push market prices to levels that make economic sense. However, because two to four years are needed to finance, engineer, and construct world-scale methanol plants (often in locations with little infrastructure), a serious tightness in supply could occur in the mid-1990s, Crocco says.

In 1984, U.S. methanol consumers became partly dependent on imports when several plants were shut down as falling prices made them unprofitable. Because consumption has grown faster than capacity, roughly a quarter of the U.S. supply now stems from the excess of imports over exports. With future U.S. energy costs increasing, the cost of making methanol will increase. Consequently, investment returns for U.S. plants could remain less competitive than foreign plants that continue using low-cost gas.

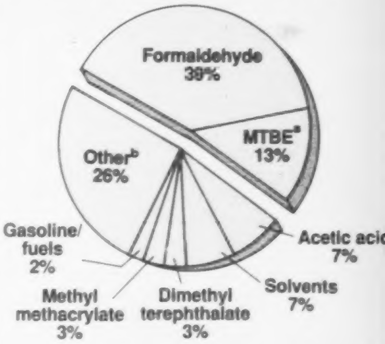
Shifts of methanol from other uses to MTBE could occur, Crocco says. He cites the example of formaldehyde, which consumes more than a third of world methanol output. In the U.S., a slowdown in home building is reducing growth in the demand for formaldehyde for making adhesive resins used in plywood and particleboard.

As phasedown of the use of lead alkyls in gasoline continues worldwide, growth in MTBE use will remain high. MTBE consumption also will continue to increase in the U.S. as the potential remains for its greater use in reformulated gasolines needed to meet future clean air regulations.

MTBE growth could temporarily be slowed by the limited supply of isobutylene. However, numerous petroleum refinery projects are under way or have been planned to increase isobutylene output. If a large part of these projects is completed, and methanol capacity grows slowly, the limit on MTBE supply in the mid-1990s could be methanol, not isobutylene, Crocco suggests.

Bruce Greek

Formaldehyde, MTBE make up half of global methanol use



1990 global methanol consumption[c] = 6.1 billion gal

a Methyl *tert*-butyl ether. b Largely as intermediate for chemical manufacture. c Forecast. **Source:** Crocco & Associates

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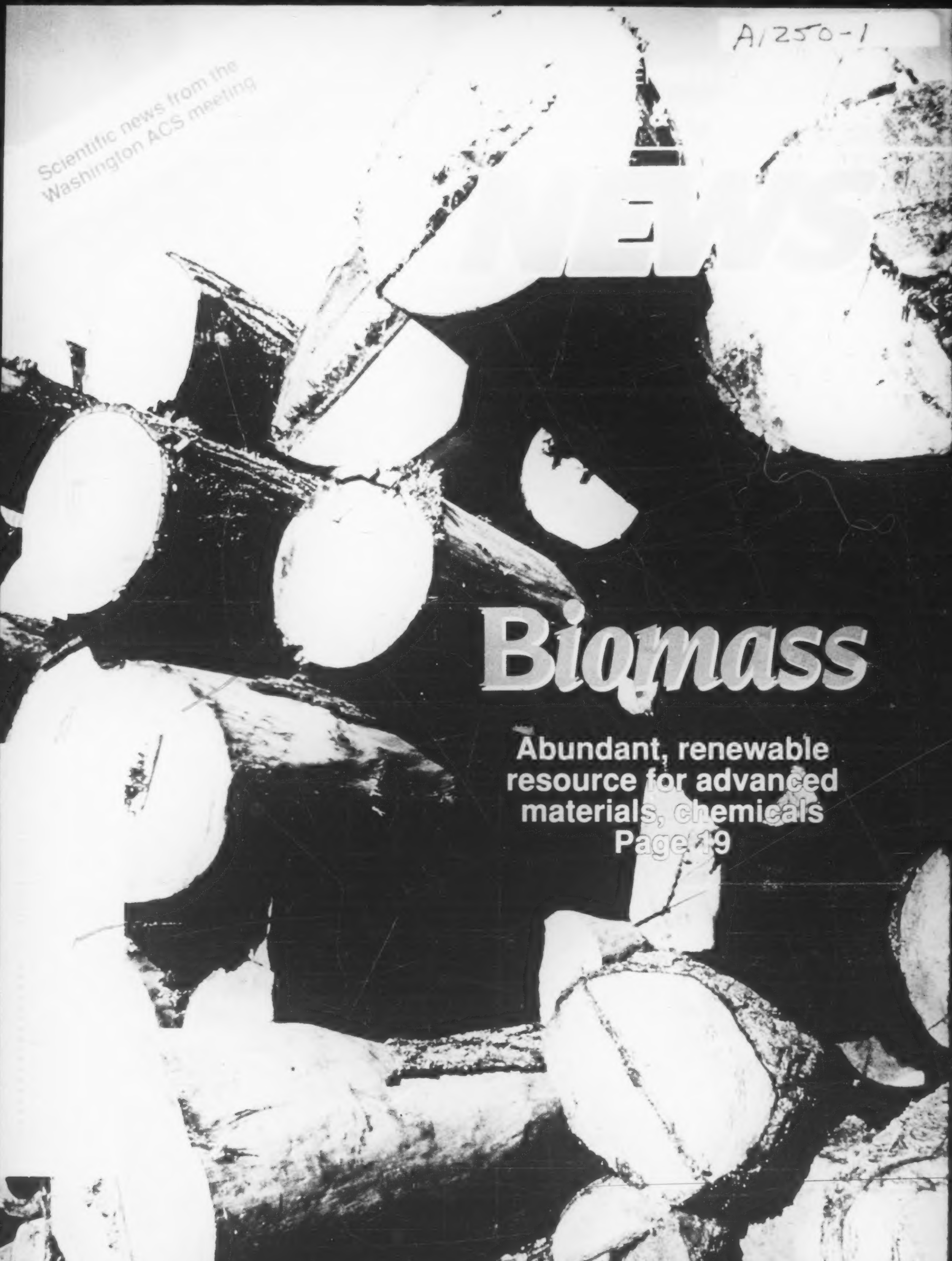

Scientific news from the Washington ACS meeting

Biomass

Abundant, renewable resource for advanced materials, chemicals
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CHEMICAL & ENGINEERING NEWS

SEPTEMBER 10, 1990

News of the Week

- A fuel leak again grounds space shuttle *Columbia* and delays Astro-1, a spacelab mission designed to make round-the-clock observations with UV and x-ray telescopes. Page 4
- Scientists isolate a gene mutation that is responsible for a common form of osteoarthritis. Page 5
- ACS files countersuit against Dialog seeking $40 million in damages for breach of contract, breach of obligation of good faith, and fraud. Page 5
- Delegates to UN-sponsored conference agree to draft assessment as step toward treaty aimed at halting global warming. Page 6
- Argonne researchers devise chemical process for extracting, recovering ^{90}Sr from liquid nuclear wastes. Page 6

Business

Chemicals have become a big part of Shell's business, boosting it to the seventh largest chemical firm in the world. **Page 9**

Government

Less use of fossil energy and more funding of energy-related R&D were called for recently both by participants at an ACS press conference on responses to the Mideast situation and in a report from the National Research Council. **Page 16**

Science/Technology

From the Washington meeting: new technique for formation of nanomaterials developed; all-organic, optically clear, solid-matrix, radioluminescent lights developed by Sandia chemists; scanning tunneling microscopy images of lysozym and chymotrypsinogen A deposited on graphite surfaces reveal protein molecules in ordered arrays. **Page 23**

ACS News

People and events from national meeting are shown in photos; more PRF grants approved. **Page 30**

Cover: Photo by Royce Bair, Uniphoto Picture Agency

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Cover Story

Resurgence of interest in producing new materials, chemicals, and fuels from biomass resources sparks active R&D efforts, but greater federal commitment is urged. Page 19

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LETTERS

CHEMICAL SAFETY

Explosion hazard for chloroalkyl silanes

The letters from Keith A. Horn (C&EN, June 4, page 2) and Jonathan D. Rich (C&EN, March 26, page 2) prompt me to call attention to related observations of explosion hazards for chloromethyl silanes [Kaesz, H. D., Stone, F. G. A., *J. Chem. Soc.*, 1433 (1957)].

The exchange of each mole of C-Cl bond with one mole of Si-H bond is exothermic. Bond enthalpies (in kJ mol^{-1}) [from Johnson, D. A., "Some Thermodynamic Aspects of Inorganic Chemistry," 2nd ed., Cambridge University Press, New York (1982)] are: $\text{C-H}\ (413) + \text{Si-Cl}\ (400) - \text{C-Cl}\ (346) - \text{Si-H}\ (318) = +149\ \text{kJ mol}^{-1}$.

Lewis acids are known to catalyze this process, which when intramolecular is known as the Whitmore rearrangement. Thus the hazard of an exotherm exists for any haloalkyl silane, and not just for the cases cited in the above-mentioned letters. The bumper-sticker equivalent of "I Brake for Trees" for chemists involved in synthesis should be, "I Brake for Thermodynamics."

Herbert D. Kaesz
University of California, Los Angeles

Misuse of homochiral

We want to commend Stu Borman on the timely and important article, "Chirality Emerges as Key Issue in Pharmaceutical Research" (C&EN, July 9, page 9), which alerts your readers to a current problem of considerable interest. Unfortunately, however, the widespread misuse of the term "homochiral" in the sense of "enantiomerically pure" was propagated in this article, despite concern previously voiced in this column (C&EN, Nov. 4, 1985, page 5) and despite the fact that the editor of the *Journal of Organic Chemistry* frowns on this misuse of the term.

The term homochiral was coined by W. Thomson (later Lord Kelvin) in his Baltimore Lectures (1884, published 1904). It is derived from the Greek "homos," which means same, and "cheir," which means hand, and thus means objects or molecules of the same handedness (or sense of chirality or configuration). Thus left hands (of different individuals) are homochiral as are molecules of (+)-tartaric acid. A sample of (+)-tartaric acid is made up of homochiral molecules, but it is inappropriate to therefore call the sample (or the substance) homochiral just as one does not call a notepad "identical" just because it is made up of identical sheets of paper.

The appropriate term to use for a configurationally homogeneous sample—i.e., one made up of chiral molecules of one and the same configuration—is "enantiomerically pure"—a term, in fact, repeatedly and correctly used in the above article. If a single word is preferred, we propose the abbreviated form "enantiopure."

Ernest L Eliel
Samuel H. Wilen
University of North Carolina

ACS and UNESCO

I noted in a Government Concentrate (C&EN, June 4, page 14) that our society sent a letter to President Bush and Secretary of State James Baker saying that it was "crucial that the U.S. return to . . . the United Nations Educational, Scientific & Cultural Organization and fund it . . . at the level the U.S. provided . . . in 1981."

I have written letters to President Bush and Secretary Baker informing them that this action was not taken with the concurrence of the membership and over what would have been some protest. The U.S. rightly withdrew from UNESCO in 1981 after it became obvious that the organization had degenerated into an anti-U.S. and anti-Western World propaganda instrument. Even with a change of director-general, the stance has only slightly changed (from violent anti-Americanism to only strident anti-Americanism)! One does not fund one's enemies.

In my 23 years of ACS membership, I have noted a distinct political shift of the organization to the political left. This is most unfortunate. ACS should

More Energy Research Called for To Stem Oil, Climate Change Crises

ACS press conferees, National Research Council report agree—meet crises by using less fossil energy and spending more on energy R&D

Janice R. Long, C&EN Washington

Oil in particular and fossil fuels in general were the topic of much discussion in Washington, D.C., during the last week in August. At the 200th national meeting of the American Chemical Society, participants in a press conference pulled together by the ACS News Service addressed the question of appropriate responses to the looming energy crisis posed by the Mideast situation.

Meanwhile, the National Research Council, responding to a request from Congress and with funding from the Department of Energy, issued a report assessing what energy policies and R&D strategies the U.S. might pursue if it decided that stabilizing atmospheric concentrations of so-called greenhouse gases, which seem to contribute to global climate change, were wise courses of action.

Both groups came up with the same answers to what, on the face of it, might seem to be two very dissimilar problems: Put more, a lot more, research emphasis on renewable energy sources, improved methods of employing fossil fuels, energy conservation, and energy efficient technologies. Those, however, are long-term answers. In the short term, the best answer to both problems, both groups agree, is to use less fossil energy.

The NRC Committee on Alternative Energy Research & Development Strategies emphasizes the importance of conservation or more efficient use of fossil fuels as the best near-term (from the year 1990 to 2000) way to reduce emissions of carbon dioxide and other greenhouse gases. In that time, the committee says, R&D can have little effect on the adoption of greenhouse-gas-reducing technologies that already exist but are not currently used.

Incentives and regulations by the federal government—such as taxes, tax credits, energy efficiency standards, loan guarantees, subsidies, and liability limitations—can have major influence. "In the event that the nation makes a commitment to reduce emissions of [greenhouse gases] significantly, such actions ought to be considered" as a supplement to the two R&D strategies laid out in its report, the committee says.

The first or "focused" R&D strategy involves pursuing energy R&D that, although aimed at reducing greenhouse gas emissions, also makes sense for reasons other than a concern about global climate change. The second or "insurance" strategy calls for pursuing energy R&D that would be viable only in the presence of concerns about global climate change. In both strategies, the report says, federal funding is needed because of the inability of private firms to capture the benefits of basic research and because the price of fossil fuels is less than the full cost to society associated with their use.

Either program would require a major change in emphasis in DOE's energy R&D programs, because, as the committee says, "only limited investments are being made in technologies relevant to the reduction of [greenhouse gas] emissions." For example, the report points out that federal funding for DOE's civilian energy R&D in the solar and renewables program fell 89% on a constant-dollar basis from fiscal 1979 to fiscal 1989. During the same time, conservation program funding declined 61% and electric energy program funding 76%.

Thus as a first step, the committee recommends DOE reallocate $300 million in funds on a sustained basis to research programs aimed at increasing energy productivity by achieving high levels of energy efficiency in electricity generation and in buildings and transportation; increasing recycling of materials; and gaining a better understanding of processes involving biomass production and conversion—to name just a few. In addition the committee says research is needed to foster the development of and shift to the use of low or nongreenhouse-gas-emitting energy technologies.

Many of the changes in DOE's research emphasis suggested in the NRC report, "Confronting Climate Change: Strategies for Energy Research & Development," would also work to lessen the U.S. dependence on foreign oil, which was discussed at the ACS news conference. As James L. Gaddy, distinguished professor of chemical engineering at the University of Arkansas, pointed out, the U.S. decided 15 years ago that it would be energy self-sufficient by 1990. That effort was "not very successful," according to Gaddy, noting that in 1975 the U.S. imported 30% of the crude oil it consumed. Imports now account for 54% of oil used.

It's not that the U.S. suffers from a lack of energy sources, Gaddy notes; it has plenty of coal reserves. "What we are short of in this country are liquid fuels. We need transportation fuels." His solution to energy shortages focuses on both renewable energy sources and improved methods of employing fossil fuels. Gaddy points out work—also the subject of a paper presented at an ACS Division of Fuel Chemistry symposium—that he and his colleagues are doing on the biological production of liquid fuels from biomass and coal. They have microorganisms, he says, that can produce ethanol from biomass, convert natural gas into ethanol, and convert gasified coal into liquid fuels.

These microorganisms, Gaddy says, are very energy efficient. They work at ordinary temperatures and pressures and so offer significant advantages over chemical processes used to produce liquid fuels from coal. These chemical processes are too expensive to compete with oil-based fuels, even at today's relatively high prices. Gaddy, whose work has been supported by DOE, thinks that biological conversion can be done economically now that its technical feasibility has been established on a small scale. What's needed now, he says, are large-scale demonstrations, which could take four to five years. The problem, he adds, is finding the money to do the scaleup.

The medium-term solution to potential energy shortages offered at the ACS press conference by Douglas G. Naae, a research scientist for Texaco's exploration and production technology division in Houston, focuses on using a renewable resource—lignin—to recover a nonrenewable resource—oil. Naae points out that the U.S. consumes about 16 million barrels of oil each day, with about half of that coming from domestic wells. Based on today's prices and using today's technology, he says, the supply from currently operating U.S. wells will last about eight to nine years.

However, Naae says, and further indicated in a paper given at a symposium for the ACS Division of Cellulose, Paper & Textile Chemistry, the U.S. could add the equivalent of 50 years' supply, or 150 billion bbl, to its reserves using chemical flooding technology, which uses surfactants to flush the oil in underground reservoirs to production wells so it can be pumped to the surface. It has been known for some time that the process, called enhanced oil recovery, works. However, it's generally been just too expensive to use this process because of the high prices and limited quantities of the necessary chemicals. An oil price of $35 to $40 per bbl is needed to make enhanced recovery profitable, according to Naae.

Given the situation in the Middle East, prices may go that high. However, the technology being developed by Texaco is much more economical, Naae says, because it starts with lignin-based chemicals. Lignins are produced in large quantities, approximately 250 billion lb per year in the U.S., as by-products of the pulp and paper industry. As a consequence, the price of some lignin products, such as lignosulfonates, are as low as 2 cents per lb. Although lignin chemicals have many applications, such as in drilling muds, as binders for animal feed, and as the base for artificial vanilla, Naae says they have not previously been used as surfactants for oil recovery.

Energy R&D budget is half of what it was after '70s crises

$ Millions[a]	1989	1979	% change 1979–89
Fossil energy	$ 528	$1035	−49%
Basic & supporting research	438	297	47
Magnetic fusion	305	327	−7
Nuclear fission	293	1356	−78
Biological & environmental research	217	302	−28
Conservation	135	350	−61
Uranium enrichment	115	203	−43
Solar & other renewables	105	929	−89
Energy Information Administration	63	61	3
Electric energy	36	147	−76
TOTAL	**$2235**	**$5007**	**−55%**

[a] Constant 1989 dollars. **Note:** Excludes funding for DOE's general science programs, human genome project, and Superconducting Super Collider project. **Source:** National Research Council

According to Naae, lignin chemicals can be used in two ways in chemical floods for enhanced oil recovery. In one method, lignosulfonates are blended with tallow amine and conventional petroleum sulfonates to form a unique mixture that costs about 40% less to use than chemicals made solely from petroleum or petroleum-based products.

In a second method, the lignin is reacted with either hydrogen or carbon monoxide to form a new class of chemicals called lignin phenols. These phenols, because they are soluble in organic solvents, but not in water, are good candidates for further conversion to chemicals useful in enhanced oil recovery, he says.

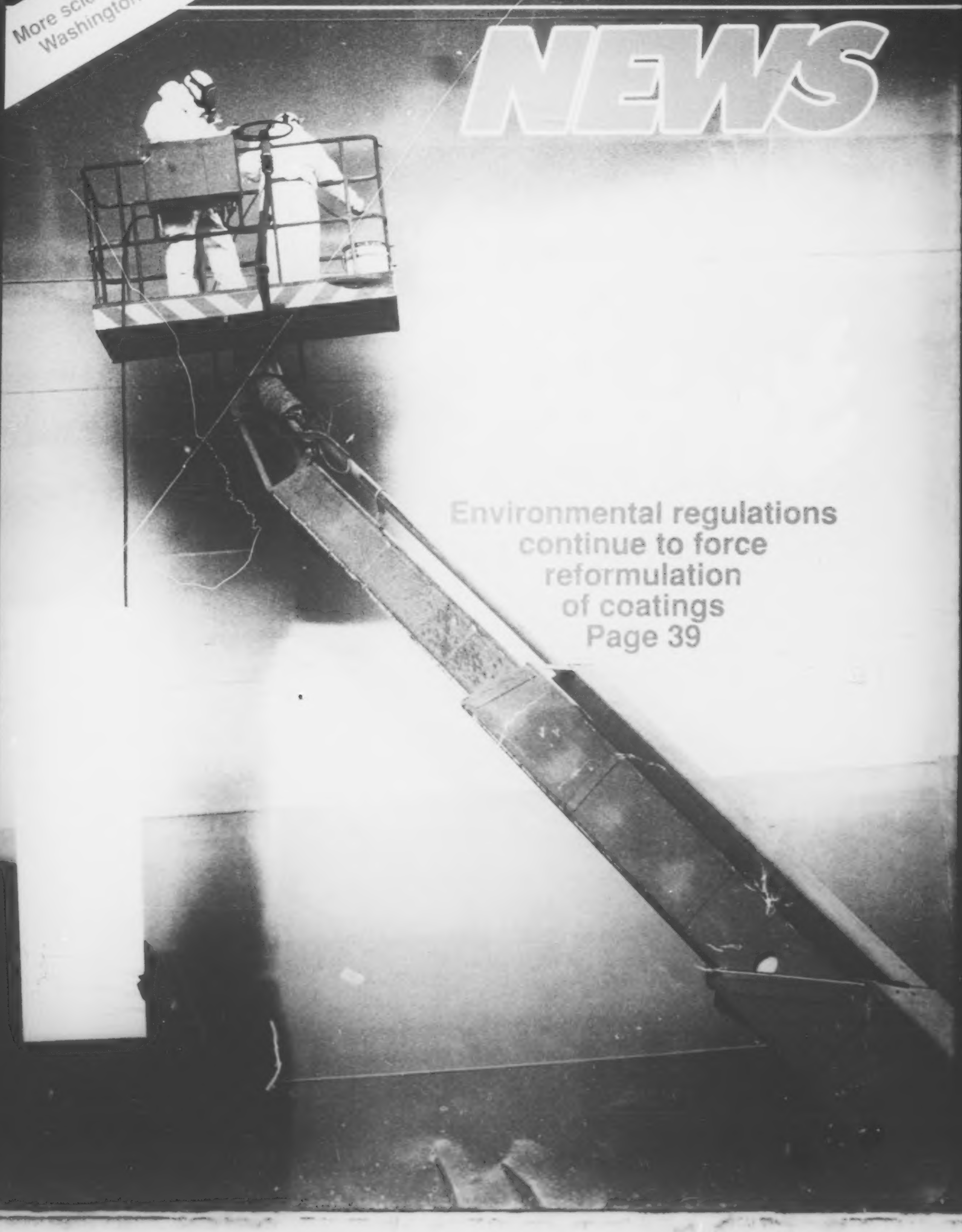
Christopher Flavin, vice president for research at the Worldwatch Institute and speaker at a symposium sponsored by the ACS Division of Environmental Chemistry, took a different tack from the other two speakers at the ACS press conference. He says it is important to keep in mind, when viewing the impending oil crisis in the Mideast, that it is the U.S.'s own increased consumption of oil that has gotten it once again into a potentially precarious situation. Flavin contends that finding strategies to restrain U.S. consumption of oil would be a much more economical strategy over the next 10 years than one relying on alternative energy sources, such as synthetic fuels. Such fuels were touted 15 years ago but proved to cost much more than people were willing to pay in times of relatively cheap energy. And conservation is a viable option, he maintains, pointing out that the technology to produce cars with fuel efficiencies of 40 miles per gallon is available now. If all cars got that mileage, the U.S. could be saving 3 million bbl of oil per day by 2000.

Flavin also notes that the energy industry, be it conventional or alternative, is facing very different environmental requirements and conditions from those that existed during the previous energy crises. For example, given the need to worry about carbon dioxide emissions, Flavin says, developing synthetic fuels would be a disastrous course to follow—even if they proved to be economical, from an environmental point of view. ◻

More scientific news from the Washington ACS meeting

SEPTEMBER 17, 1990

CHEMICAL & ENGINEERING NEWS



Environmental regulations continue to force reformulation of coatings
Page 39

CHEMICAL & ENGINEERING
NEWS
SEPTEMBER 17, 1990

Volume 68, Number 38
CENEAR 68 (38) 1–92
ISSN 0009-2347

News of the Week

- **Massachusetts Institute of Technology appeals NSF decision to award National High Magnetic Field Laboratory to a Florida State University consortium.** Page 4
- **Regional Environmental Center for Central & Eastern Europe in Budapest opens its doors, begins efforts to reverse region's environmental damage.** Page 5
- **Threat posed by Iraqi chemical weapons has been exaggerated by the press, according to panelists at recent Congressional briefing organized by the American Association for the Advancement of Science.** Page 5
- **Two biotech firms caught in patent conflict over single-chain antigen-binding proteins.** Page 6
- **House subcommittee report calls for new laws, regulations to deal with scientific misconduct, conflicts of interest in biomedical research.** Page 6

Cover: Workers spray paint on container ship. Photo courtesy of Courtaulds Coatings

Business

Tosoh Corp. is bolstering its petrochemical operations; catalog approach to technology licensing will be used at fair near London. **Page 13**

Government

Changes in risk assessment management of problem chemicals called for; policies must be devised to prevent the U.S. from losing access to technology developed abroad; draft treaty on harmonizing world patent law presents some hard decisions for the U.S. **Page 17**

Science/Technology

From the Washington meeting: Human genome project presents challenge, but also opportunity, to analytical chemistry community; study links radon levels in water supply of private homes to higher cancer risk; recent fluoride bioassay study questioned as too lenient; advances made in approaches to engineering enzyme activity; new high-analysis phosphate fertilizer process could also cut production of waste products; fire-extinguishing halons are proving hard to replace; compact, benchtop LC/MS from Extrel introduced; Noxso process to undergo major stack-gas cleanup trial in Ohio; organic vapors change color of Pt-Pd salts. **Page 21**

Books

"Managing Creativity in Science and Hi-Tech" by Ronald Kay misses the mark in focus on creativity. **Page 73**

ACS News

ACS Council adopted two bylaw amendments, among other actions, at its meeting late last month in Washington; also, numerous local sections received awards for National Chemistry Week programs. **Page 75**

Product Report

Paint industry's 1989 shipments' value of $11.6 billion hits new high during a period when marine and other specialty coatings makers are reformulating products to meet environmental concerns. **Page 39**

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LETTERS

Nonlinear optical materials

Your article on nonlinear optical materials (C&EN, June 11, page 21) was timely and informative. Due to the rapid progress in this field, the statement, "Currently, scientists know of no way to prepare small particles of III-V semiconductors in solution," is no longer true. At the spring Materials Research Society meeting in San Francisco (April 16–21), M. A. Olshavsky, A. N. Goldstein, and A. P. Alivisatos reported the preparation of GaAs nanocrystals, which are soluble in quinoline. The particles were prepared using a reaction and methodology developed by Richard L. Wells and research colleagues.

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Richard L. Wells
Professor, Department of
Chemistry, Duke University

Structure of dynemicin

The article by Stephen Stinson on dynemicin, "New Anticancer Antibiotic Acts through Diradical Rearrangement" (C&EN, May 28, page 22), is misleading on a few points. Perhaps there is a natural prejudice toward the *Journal of the American Chemical Society*, but it should be noted that the structure of dynemicin was first reported almost a year ago (by the Bristol/Japan and Cornell groups) in the *Journal of Antibiotics* [**92**, 1449 (1989)]. When the structural relation to the other ene-diyne toxins and to bioreductive activation mechanisms is appreciated, the mechanism of action follows in a reasonably obvious way. This was first proposed in print earlier this year [*Tetrahedron Lett.*, 1521 (1990)] by myself and coworkers J. Gallagher and D. Cohen. Molecular mechanics calculations were used to verify the reasonableness of the mechanism. The *JACS* paper [**112**, 3716 (1990)] from the Bristol/Cornell effort, which was the focus of the C&EN article, beautifully corroborates the hypothesis with full structural details. It should also be noted that one issue later in *JACS*, a more elaborate computational analysis of the mode of action of dynemicin was presented [Snyder, J. P., Tipsword, G. E., *J. Am. Chem. Soc.*, **112**, 4040 (1990)].

Separating hypothesis from experimental fact was not clear in the statement that for calicheamicin/esperimicin "workers have found that sugar molecules attached to them are very specific for binding to DNA." That is an exciting and reasonable hypothesis with far-reaching implications. However, although it has been established that these toxins react directly with DNA oligomers in vitro, there is as yet no experimental evidence that establishes interaction of the sugar portion with DNA.

M. F. Semmelhack
Professor, Department of
Chemistry, Princeton University

Jobs for chemists?

Your editorial on an opportunity for chemists (C&EN, June 11, page 3) repeats the often heard refrain that we are not training enough American scientists. The major reason students are not studying for a degree in the sciences is simply because there are few well-paying jobs available.

We have had a number of postdoctoral candidates at our Department of Agriculture laboratory (USDA-ARS, Appalachian Fruit Research Station, Kearneysville, W.Va.). After working with us for two years, they look for a permanent job. It is typical for them to write to 50 to 100 schools or laboratories looking for work. On the rare occasion they get a reply, the salary is in the mid-20s. My colleagues at other facilities have indicated that their students or postdocs are having similar experiences. Few are able to make a living in science.

What is the point of studying for a career that does not exist? At the present time the smart kids are sticking to the basics: medicine, law, engineering, and business. Why spend $100,000 on a B.S. degree and work for starvation wages in graduate school only to get a degree in a field without jobs? I would like to think that if you are smart enough to get a Ph.D. in something, you would be smart enough to see if you could earn a living at it. The word gets around.

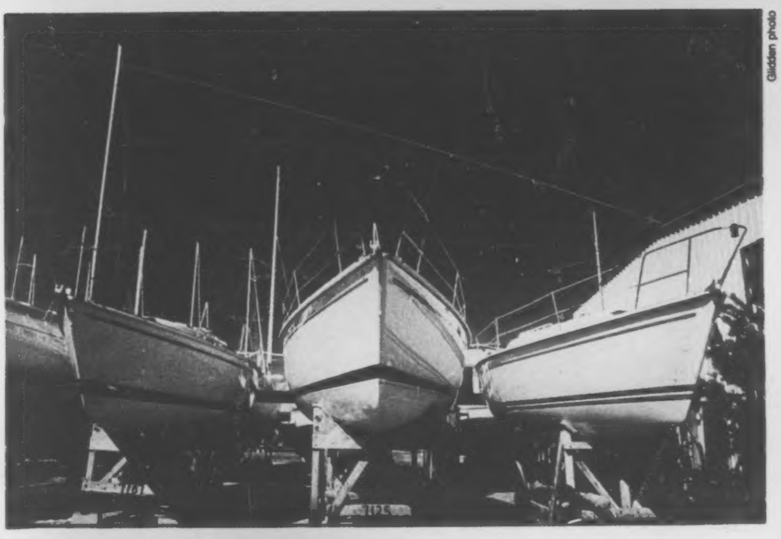
These calls for more money to train future chemists or other scientists are

Corrections

- Aug. 27, page 3: In the letter on Avogadro's number, the definition of atomic mass unit (u) should read u = 1/12, not 1/2; the mole of lawyers should be 4.9×10^{25} kg, not $4 \times 9 \times 10^{25}$ kg.
- Sept. 3, page 3: In the letter on video terminal hazards, the reference in the last paragraph to an article in the *New Yorker* should be June 26, 1989, not 1990.

PRODUCT REPORT

Marine paint makers strive to meet environmental concerns



Glidden photo

Dow Chemical photo

Specialty paints (above) serve to protect fiberglass hulls. Technician applies powder coating to test panels

Marc S. Reisch,
C&EN Northeast News Bureau

The value of paint shipments in 1989 reached a new high of $11.6 billion. However, paint shipment volumes declined 2% from the previous year, dipping to 1.04 billion gal.

An analysis of government statistics of the paints and coatings industry follows on this page. These statistics show that the value of shipments and cost per gallon of paint sold increased in all categories. But actual shipment volume rose only slightly for architectural and special-purpose coatings and actually declined in product coatings.

Manufacturers of marine coatings—the focus this year of C&EN's examination of a high-value-added component of the product coatings and special-purpose maintenance category—are under environmental pressure like their counterparts in the architectural category examined in last year's report (C&EN, Oct. 30, 1989, page 29). Increasingly, manufacturers are reformulating to reduce smog-producing volatile organic compounds (VOCs), and reformulating with water-borne coatings where possible. In addition, manufacturers of paints used to protect oceangoing vessel hulls below the waterline are grappling with legislative limitations existing or pending that would limit or ban the use of organotin polymers that discourage barnacle growth. A discussion of how paint makers are grappling with these new limitations as well as those posed by the eventual phaseout of chlorinated rubber in marine paints because of their ozone depletion potential begins on page 43.

Even as liquid coating manufacturers reformulate to increase environmental acceptability, powder coatings manufacturers say their pollution-free materials are just beginning to achieve their potential. Powders are 100% solid coatings that have neither VOC problems nor waste disposal problems. In an examination that begins on page 54, manufacturers and material suppliers discuss the growth of powder coatings as well as improvements in technology that may expand the substrates to which powder may be applied from the metal substrates coated today.

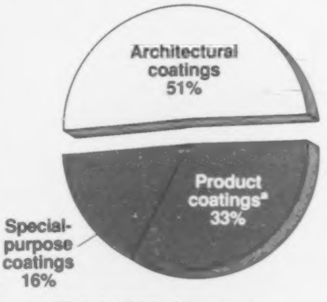
Liquid coatings, though, are still the most versatile coatings available. To deal with the waste generated when a significant percentage of spray solids do not coat a part, original equipment manufacturers (OEM), particularly in the automotive business, are using more sophisticated chemical systems to capture and separate paint solids for reuse. Beginning on page 64, manufacturers of paint detackification systems discuss work in the reuse of dried paint sludge as a cement kiln additive or as a filler in sound-deadening paint and fillers in adhesives and sealants.

Shipments declined 2% last year

As the U.S. economy slowed in 1989, especially during the second half of the year, U.S. paint makers shipped only slightly more than 1 billion gal of paints and coatings, according to the most recent data from the Department of Commerce. That figure marks an almost 2% decline in volume compared with 1988 and puts industry shipments below the 1987 level.

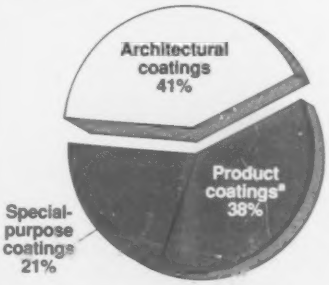
The value of industry shipments continued to rise in 1989, but the increase could not have resulted in big profits for paint makers. Although the Department of Commerce figures show that the value of 1989

Architectural coatings lead in shipments . . .



Total 1989 shipments = 1.04 billion gal

. . . and tally highest in value of shipments



Total 1989 value = $11.6 billion

a As reported by original equipment manufacturers.
Source: Bureau of the Census

shipments rose 7.9% from 1988 to $11.6 billion, paint material prices continued to soar—up almost 12% during the same period. Even if inflation and increased labor and shipping costs were not a factor (and they were), it was not a good year for the paint industry overall and could only have encouraged the industry trend toward consolidation.

Preliminary 1990 government data do not indicate this year will be much better than 1989. Although paint shipments for the first six months of this year improved marginally to 530 million gal, the value of shipments increased 5.8% in the same period to $6.1 billion. But just as paint material prices rose in 1989, squeezing profits, they did so again in the first six months of this year when the Department of Labor's statistics indicate paint material prices increased 6.4%.

In addition to pressures paint manufacturers are experiencing because of increasing raw material costs, they continue to feel the pressure to reformulate coatings in response to regulatory demands for a reduction of VOCs that may be emitted as liquid coatings dry. And they cannot easily pass along price increases in a very competitive market where about 900 paint manufacturers compete for much of the same business.

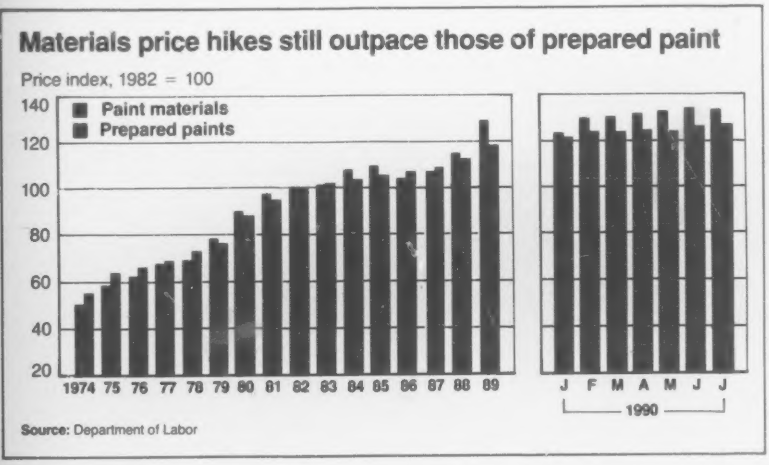
With margins under so much pressure, it is not surprising to see a well-known paint maker the size of DeSoto sell its huge paint business. Though an unfriendly takeover bid by a New York City investment group, Sutton Holdings, nudged DeSoto to sell its paint interests, a sluggish architectural and industrial paint market had limited DeSoto's profitability. In July, DeSoto agreed to sell its architectural coatings assets to Sherwin Williams for $80 million. Following that announcement, Rohm & Haas said it would purchase a former DeSoto latex emulsion and resin plant that Sherwin Williams had acquired from DeSoto. DeSoto also agreed to sell its industrial coatings business to Courtaulds for $135 million. Courtaulds, in turn, arranged to sell Valspar Desoto's coil, appliance, specialty, and packaging coatings business for $46 million, and sold to DSM Resins, the radiation cure and optical fiber coatings businesses it operated with DeSoto in a joint venture, for an undisclosed sum. Courtaulds retained the aerospace coatings business.

More evidence of cost pressure affecting paint formulators during the current year was in the Environmental Protection Agency's announcement early in July that it would ban the use of mercury in interior architectural paints. The lesson here is that the shift to water-borne formulations from solvent paints is not without environmental and health risks—the water-borne formulas require a biocide such as mercury. Formulators who had not already done so had to find alternatives, such as cuprous oxide and organotin polymers.

Early in June paint formulators were put on notice that at least one consumer group had targeted a phaseout of methyl chloroform, also known as 1,1,1-trichloroethane, well in advance of industry expectations. The Washington, D.C.-based Natural Resources Defense Council called for a consumer boycott of household products containing the solvent in order to force industry to cease use of the solvent widely acknowledged in government and industrial circles as a chemical capable of depleting the atmospheric ozone layer. Though chlorofluorocarbons 11 and 12 are more potent depleters of atmospheric ozone, and also more widely used, paint formulators must acknowledge them as another potential problem. Fortunately, trichloroethane is not a widely used coatings solvent. Industry sources say U.S. coatings formulators use about 35 million lb of trichloroethane annually. The Freedonia Group, a Cleveland-based consulting firm, estimated in its Paint, Polymers & Chemical report, that the coatings industry used 3.4 billion lb of solvents in 1988. Trichloroethane use is therefore only 1% of all solvent use in coatings.

Trichloroethane manufacturers such as Dow Chemical and PPG Industries agree that a timetable to replace the product will have to be put into place. Up until now, trichloroethane has proved valuable in replacing smog-producing solvents. However, manufacturers now must spend the money to reformulate and produce coatings that contribute very little to atmospheric smog formation without the aid of trichloroethane or be forced to withdraw products from highly regulated markets.

A 1989 profile of this dynamic if not always robust industry, based on Bureau of Census figures, shows that architectural coatings, which include both interior and exterior house paints, make up slightly more than half of all paint sold in the U.S. Product coatings for the OEM market, which includes automotive and appliance coatings, account for some 33% of U.S. paint volume. And special-purpose coatings make up about 16% of total paint shipments. This category includes large-volume maintenance items, automotive refinishing, and coil coatings.



Materials price hikes still outpace those of prepared paint

Source: Department of Labor

Shipments of architectural coatings in 1989 increased only marginally from the previous year to 533 million gal. The value of those shipments, however, rose 8.2% from 1988 to $4.73 billion, and the unit price per gallon rose 7.9% to $8.88. Architectural coatings volume did not decline despite the lag in new housing starts, as moderate prices continued to afford consumers the ability to redecorate with a modest investment in paint, even as they may be delaying purchases of more costly durable goods such as appliances and automobiles.

Product shipments for the OEM sector, however, declined 7.4% to 337 million gal, even as the government's estimates for 1988 shipments were revised downward to 364 million gal. The value of shipments rose in 1989 to $4.35 billion, up 7.1% from the previous year. Unit prices per gallon increased nearly 16% to $12.91. A portion of that increase in shipment value and unit price continues to be related to the cost of reformulated higher solids, paints OEM manufacturers must increasingly use to meet ever more stringent VOC limits.

Special-purpose coatings shipments and value both increased in 1989. According to the government figures, special-purpose coatings shipments increased 5% from 1988 to 167 million gal. The value of those shipments rose 8.8% to $2.48 billion, and the unit price per gallon rose 3.8% to $14.88.

According to the Department of Labor, indexes covering both paint materials and prepared paint show that prices continued to rise in the first six months of 1990. In that period, the index for paint materials prices rose 6.4% from last year's first six months to 132.5 (1982 = 100). While prices of most paint material categories remained steady or declined over the six-month period, solvent prices rose 20% since January from an index of 74.9 to 90.2 in June. However, emphasizing the cyclical nature of the solvent market is the fact that the June solvent index price was still 10% lower than it was in June 1989.

Titanium dioxide prices, which rose steadily last year during the first six months, were actually 1% lower in this year's first half. Prepared paint prices continue to lag behind increases in raw material prices, just as they did during the first six months of last year. The Department of Labor's index for prepared paint prices rose only 2% between January and June of this year to an index of 124.7. The lag continues to reflect manufacturers' reluctance to raise prices too rapidly for fear of losing share in a competitive market.

On an average annual basis, paint materials costs increased only 6.5% between 1974 and 1989. Prepared

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paint costs rose 5.3% over the same period. Clearly this is an industry that depends overall on volume sales rather than price increases to maintain profitability. And where price increases barely keep pace with inflation, manufacturers must survive by gaining market share and improving manufacturing efficiencies.

Though the Census Bureau reports actual shipments of paint declined in 1989, the Department of Labor reports total employment in the paint industry increased. The number of production and nonproduction paint industry workers rose 2.6% last year to 63,400 compared with a revised 61,800 for 1988. If the Department of Labor does not revise its industry employment estimate for 1989, the paint industry will have produced 98 million gal more paint than when Labor last estimated the industry employed 63,500 workers in 1985.

The number of both production and nonproduction workers increased between 1988 and 1989. Nonproduction employees of paint firms rose 0.3% in 1989 to 31,300; production employees increased 4.9%. However, between 1980 and 1989, employment of production employees declined 2.4% to 32,100. The level of nonproduction employees decreased 2.8% during the same period.

Marine paints: durable yet gentle to environment

Marine coatings comprise a specialty segment of the world paint market. Paints supplied to this market must survive under the harshest environmental conditions and so suppliers must formulate the most durable coatings available. But recently these high-value-added paints costing between $100 and $200 a gal have come under many of the same pressures that have forced other industrial paint makers to reformulate paints to lower VOC levels. In addition, because they are formulated to deter the formation of barnacles, organotin compounds used as the primary antifouling ingredient in paints applied to ship hulls below the waterline are implicated in the destruction of marine life. Also, concern over the ozone-depleting potential in the manufacture of chlorinated rubber compounds used in deck and surface shipboard applications has meant that paint manufacturers have had to develop alternatives.

According to Mark Davies, marine marketing director of Courtaulds Coatings, marine coatings represent a $1 billion worldwide market. Davies says his company holds in excess of 30% of the marine coatings market where Courtaulds Coatings is best known by its International label. There are three key segments of the marine market, he says: new ship paints, maintenance and repair paints applied to ships in dry dock, and sea store paints that crews apply to vessels at sea. Davies also outlines three major customer segments: shipping companies who own fleets and manage the fleets themselves, fleet management companies, and shipyards.

Major shipbuilding countries that build and paint new oceangoing vessels are South Korea and Japan, and together with China and Taiwan, they hold about 60% of the ship tonnage on order, says Davies. Other major shipbuilding countries are Yugoslavia, Poland, Denmark, West Germany, Italy, Spain, and Brazil. The U.S. builds almost no major large commercial vessels, though new military ships do require paint.

Commercial vessel repairs in dry dock are mostly performed in countries with a comparative labor cost advantage, although currently dry dock capacity, flexibility, and efficiency are key, says Davies. Singapore and Japan together have about 40% of the dry dock maintenance and repair paint market by vessel deadweight, says Davies. South Korea, Dubai, and Portugal each have another 10%of that market. Greek and West German shipyards also do significant dry dock repair and paint work. Sea stores are set along the

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Initially, it was a hard fight to introduce the self-polishing copolymer paints to the marine industry because of the high cost of application, says Davies. Owners had to have the hull blasted before the paint could be applied. In return they received a painted hull that could go five years between dry dock periods instead of using a paint that needed reapplication each year or two. They also saved about 12% in fuel costs because the hull remained free of barnacle-produced drag. The savings, says Davies, more than paid for the additional application costs.

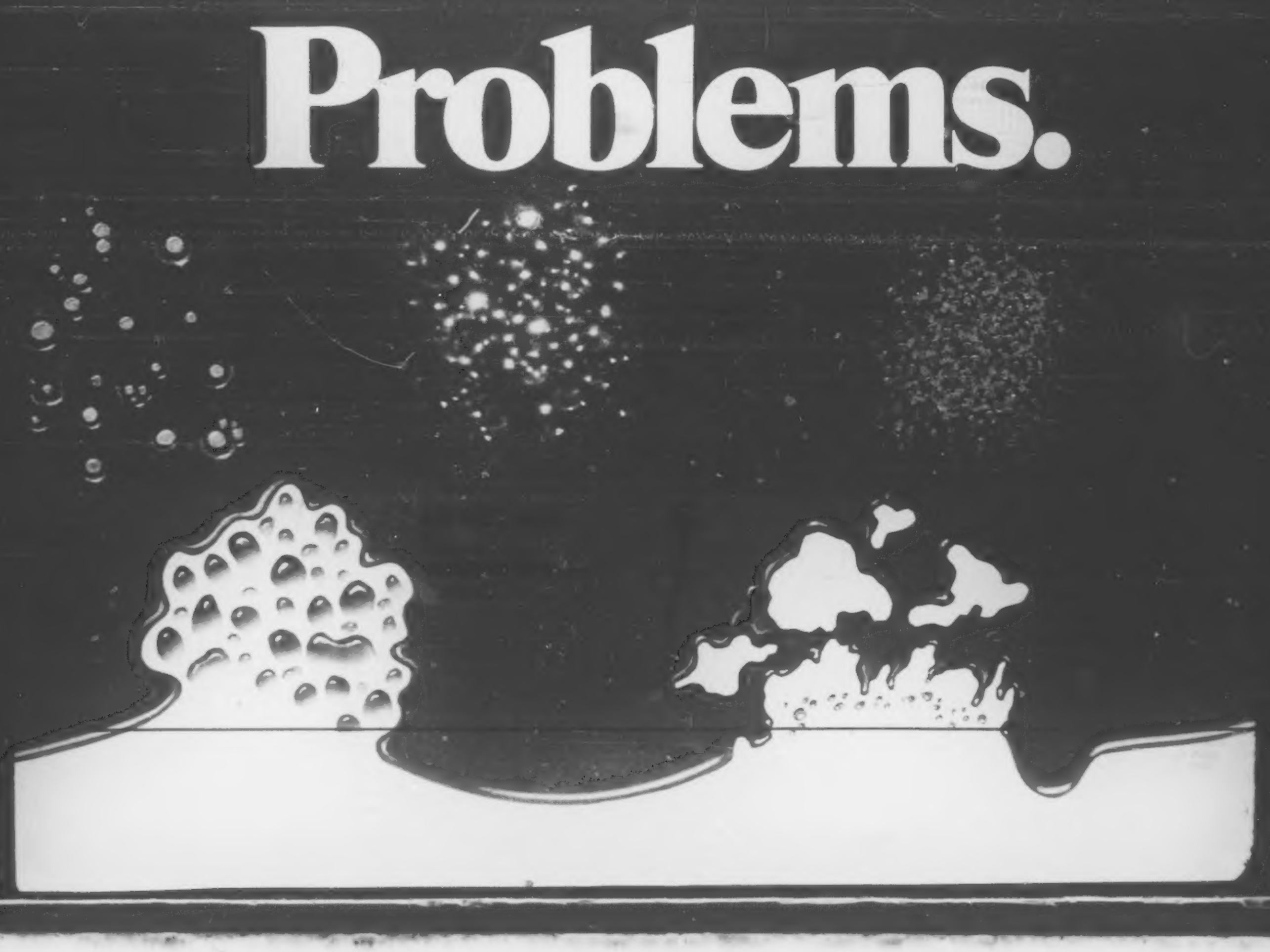
Substitutes for TBT are already available, says Davies, but they are more expensive. One is Courtaulds' Interclene BRA 500 series, which has been available since 1986 and is already in use on over 200 U.S. Navy vessels plus over 100 commercial ships. The paint is effective because of what Davies calls a controlled depletion polymer technology. Another Courtaulds hull paint, Interviron, only available outside the U.S., is TBT-free, but where the TBT-containing paint gives five years of service between dry dock spells, Interviron allows only three years and only 75% of the vessels remain virtually clean of barnacles as opposed to 96% of vessels painted with Courtaulds' TBT-containing paints.

Above-water-line coating systems vary, says Davies, and include alkyd, chlorinated rubber, epoxy, and polyurethane systems. Courtaulds produces unique antiabrasion paints called Intershield, a modified epoxy coating for decks and cargo holds, says Davies. Another recently introduced epoxy-type ballast space paint, the Intergard KB 400 series, can withstand 25 years under the wet-dry conditions it must endure, he says.

Courtaulds supplies VOC-compliant coatings worldwide, says Davies. But legislation expected in other world port markets will require that Courtaulds bring the low-VOC technology worked out in the U.S. to European ports as needed, he adds.

Jotun, the Norwegian marine coatings supplier, also manufactures a TBT-free ablative paint it calls Hydroclean, says Paul De Vivo, general manager of Jotun Valspar marine coatings. Jotun products are manufactured and distributed in a joint venture in the U.S. with Baltimore-based Valspar. Hydroclean, says De Vivo, contains cuprous oxide and allows 30 months between dry docking periods. De Vivo says a number of longer acting antifouling paints are under development, but none are yet registered and approved for use by the EPA.

Valspar, explains De Vivo, is the exclusive U.S. licensee of Jotun. The 1986 arrangement between the two helped expand Valspar's own marine paint business when, in 1984, it acquired Mobil's marine paint business and, in 1986, Beatrice's marine paint division, Farboil.



world's major ocean trade routes. Davies says Courtaulds has about 200 marine paint distribution points worldwide and paint factories in 35 countries.

Further emphasizing the international nature of the marine paints business, Davies notes in shipbuilding, for example, a Norwegian ship operator may commission a ship to be built in South Korea using Swedish, British, or American consultants each influencing the paint decisions. "If you are not an international player, you're not in the market," Davies says. Other major world marine paint suppliers are Sigma, a division of Petrofina of Belgium; Hempel of Denmark; and Jotun of Norway. Two Japanese companies are major marine paint suppliers: Chugoku and Kansai. Davies estimates that, together with Courtaulds, these companies supply about 70% of world marine coatings.

Davies says the current move by government authorities to eliminate tributyl tin (TBT) compounds from below-the-waterline marine antifoulant paints has forced Courtaulds and others to find new biocides and polymer solutions. Legislation in the U.S., Canada, Europe, Australia, and Japan effectively bans the use of the compounds on vessels less than 25 meters in length. In addition, current legislation in North America and Australia limits daily TBT releases into the sea from paint systems to 5 μg per sq cm and 4 μg per sq cm, respectively. "That is not overly restrictive. We can formulate to that," says Davies. But only the state of Virginia has water-quality legislation that limits TBT even further, effectively banning the use of the compound on ships in coastal waters.

Governments in Japan, Hong Kong, and Europe are also discussing further TBT-restricting legislation, says Davies. "Our view is that legislation to restrict or ban TBT compounds will come in another two to three years," he says. In defense of the use of TBT-containing paints such as Courtaulds' Intersmooth SPC, Davis points out, is the fact that TBT bonds to make a copolymer in the paint that slowly erodes, allowing a controlled release of the barnacle-fighting compound.

Demand for paint chemicals to grow 5.7% by 1993

$Millions	1993	1989	% annual growth
Synthetic resins	$2225	$1570	7.2%
Pigments	1750	1234	7.2
Solvents	755	813	−1.5
Additives	355	252	7.1
Extenders & fillers	220	163	6.2
Natural oils & resins	165	123	6.1
Other paint chemicals	180	131	6.6
TOTAL	**$5650**	**$4286**	**5.7%**

Source: Freedonia Group

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Aside from TBT concerns, VOCs are becoming increasingly important, says De Vivo, particularly in the San Francisco Bay Area and in other localities. VOC concerns have also helped push waterborne coatings in the marine market where new formulas can offer the same or improved performance characteristics, he adds. Jotun Valspar plans to introduce a new high-performance, water-based enamel line of paints to replace alkyd formulations in signal and marine colors. The new line does not yet have a tradename, notes De Vivo, but the new water-based primers and top coats have been tested for exterior use, and will perform well on internal applications. Valspar's industrial maintenance coatings division had developed these newest coatings, points out De Vivo.

Another product from its industrial maintenance arsenal, says De Vivo, is a line of oil-tolerant epoxy coatings called Vepok. The epoxy mastic can go over oil-fouled damp surfaces and provide either a nonskid or smooth finish for use on interior surfaces. It has proved itself in refinery and other industrial applications, he adds.

Shipboard use of urethane-type coatings is growing, says De Vivo, but at a slower rate than in industrial maintenance markets. He believes resistance to their use in marine markets is due to the cost of these formulations relative to the cost of epoxys, alkyds, and chlorinated rubber, and also to the complexity of application.

Japan's Kansai Paint boasts $85 million in worldwide annual sales of marine paint, according to S. Nishimura, marketing manager, for the Kansai Paint America operations. The company is also grappling with the TBT issue. Nishimura says, "TBT compounds are positively expected to be banned in Japan within the year." Kansai is prepared for this eventuality and is about to introduce a new antifouling paint called Nu Current, a "TBT-free, water-soluble acrylic polymer." Nishimura adds that the new paint will provide commercial vessels with 30 months' or more service life between dry dock periods but "is 20 to 30% more expensive than existing organotin-compound-containing products."

Kansai is researching new "natural" solutions to antifoulant paint technology, says Nishimura. "We have spent the last 10 years studying such things as thrombosis in human beings, the skin of sea animals, and the surface energy of plant leaves to develop and perfect our nontoxic foul-release coatings technology, the 'Biox' system." Biox is currently in use in the power-generating industry and is being introduced to the marine market.

Chugoku, which markets in the U.S. as CMP Coatings division of Chugoku Marine Paint, has a new antifoulant paint that does not con-

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tain TBT compounds. Bioclean, says Jeffrey McKenna, general manager of industrial coatings for CMP, is a polysiloxane silicone currently used in the power industry that could also be used on oceangoing vessels except for its high cost. It is, however, being tested on Coast Guard vessels. But because it cannot be applied thickly, Bioclean is effective only two years, as opposed to TBT-containing paints with their five-year maintenance cycle.

Bioclean is a new twist on self-polishing surface coatings, says CMP's Kevin Casey, general manager of marine coatings. Where TBT-containing polymers slowly wear away and thus release the TBT antifoulant, Bioclean is a slippery coating with a surface tension lower than glass. If a microorganism attaches itself, a water flow rate of only 5 feet per second will clean off anything that attaches to the paint, he adds.

Casey says CMP also offers a line of TBT-containing compounds that meet current EPA requirements for use. In addition, CMP offers a line of service-tolerant epoxy coatings and tank coatings for product carriers. Chlorinated rubbers are popular for marine use, says Casey, because crews can touch up paint easily with them, but the manufacture of chlorinated rubbers is "not environmentally friendly." As a result, they will not be manufactured as widely. Costs are already increasing for these resins.

McKenna says an alternative for chlorinated rubber is CMP's Superbondex, an epoxy urethane coating containing between 82 and 86% solids, and which is VOC compliant. It can be painted over most existing substrates with a minimum of surface preparation. While the cost of Superbondex is currently higher per gallon than the chlorinated rubber products they replace, Casey says the cost per square foot of Superbondex is about equal to chlorinated rubber paints.

Casey says Chugoku supplies its marine paints from 53 locations in 32 countries worldwide and manufactures not only in New Orleans, but also in other countries such as Brazil, Japan, South Korea, Singapore, Taiwan, and the Netherlands.

While the big marine coatings suppliers have a broad array of coatings for large ships as well as small boats, Glidden, an ICI company, supplies only pleasure craft manufacturers. It supplies a neopental glycol isophthalic-type gel-coat for fiberglass-hulled craft that provides good gloss retention, water resistance, and good patching, says Alan W. Allen, vice president. It also supplies a proprietary resins system called Blister-Gard that can be applied to a fiberglass substrate thus reducing the problem of osmotic blistering on large pleasure craft that remain in the water for extended periods.

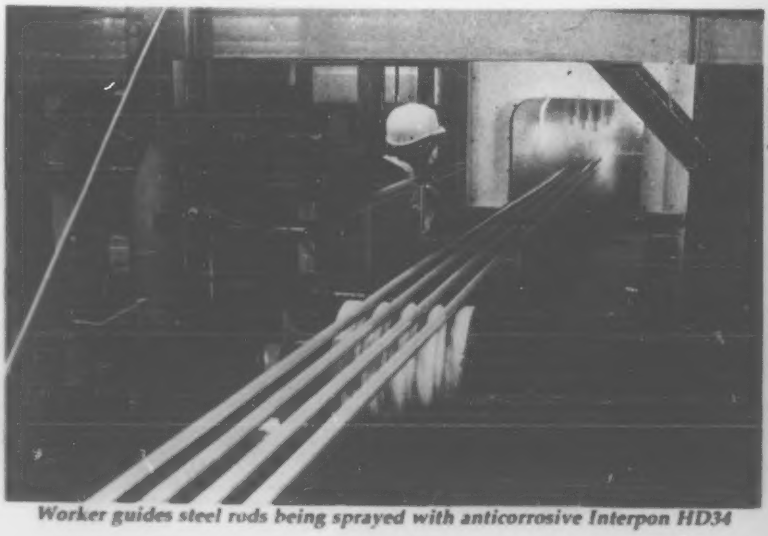
The U.S. government-supported Naval Research Laboratory in Washington, D.C., is proposing a possible high-tech solution to the antifoulant paint problem without resorting to TBT. According to Ron Price, a biologist with the lab, his colleagues at the lab, Paul Yager and Paul Schoen, discovered they could produce microcapillary organic tubules less than 1 µm across and 0.5 µm in diameter by dissolving certain lipid molecules in alcohol with the addition of water.

Price has been working with the tubules, which can absorb compounds such as the antibiotic tetracycline or copper compounds when placed in a slurry of those substances. When the tubules are then incorporated as a filler in a marine paint at the rate of 5% by volume, they slowly leach out the tetracycline, copper compound, or other slurry material. Price says he is examining natural marine proteins such as a coral extract, leptogorgia, as possible slurry compounds. He is working in association with Duke Marine Laboratories and researchers at the University of Hawaii.

Cost of the tubules is high, admits Price. The lipids to make the tubules cost about $5000 per lb, which would net 10 to 12 lb of metallized tubules. But Price believes the cost could drop when the tubules are made in sufficiently high volume. The Naval Research Lab is now looking for a commercial partner, he says, and has held preliminary discussions with International Paint, Hempel, and Nippon Fat & Oil.

One materials supplier that is eager to see more urethane used in marine coatings is Bayer. According to R. Dale Baker, director of sales and marketing for Mobay, Bayer's U.S. chemical operating arm, urethanes are used in marine environments primarily where aesthetics, arbrasion resistance, and weathering abilities are important. Two-part urethane systems are the norm in marine use, he says, with polyester urethanes in widest use. But the newer acrylic urethane systems offer the highest level of abrasion resistance and show the greatest promise for increased use in marine markets.

Rohm & Haas' David M. Watson, marketing manager for maintenance



Courtaulds Coatings photo

Worker guides steel rods being sprayed with anticorrosive Interpon HD34 and specialty coatings, says the urethane polyols materials his company supplies to urethane acrylic paint manufacturers are part of a "premiere urethane top coat system used over an inorganic zinc primer," in above-waterline marine use. Where a user may be unwilling to apply a urethane, Rohm & Haas can supply a paint maker with its Maincoat HG 54 acrylic thermoplastic emulsion. The water-borne emulsion has been used in industrial maintenance paints and is now being used for marine applications. Rohm & Haas also has a solvent-thinned acrylic resin to crosslink with an epoxy now under development for use in marine environments to compete with urethane coats, adds Watson.

According to another material supplier, M. Anthony Johnson, who is market development manager for marine and maintenance at Dow Chemical, alkyds, chlorinated rubber, and vinyl are all slated for a decline in use in marine environments. Dow supplies marine coating formulators with epoxy and polyurethane materials as well as some vinyl esters. Alkyds and vinyls are under pressure because these solvent-thinned formulas have VOC problems, says Johnson. In Europe, vinyl resins have been widely used for years, he adds, but only 26% of a vinyl paint contains solids, while the remaining 74% is composed of volatile compounds. In contrast, epoxy resins, which Dow supplies, are generally incorporated into marine paints as 60% solids and allow paint makers to achieve very low VOC output.

Johnson estimates that of the total 50 million lb of resins used in the marine market annually, 16 million lb is thermoset polyurethane or epoxy resins. While use of the latter two resins is growing annually at 1.5%, he says, the overall market for marine resins has been declining at an annual rate of 2.4%. He predicts the use of vinyl resins will show a 34% annual rate of decline between 1988 and 1993, with an estimated 6.3 million lb of vinyl resins used in the marine market in 1988 declining to 800,000 lb in 1993.

Du Pont, a supplier of chlorinated rubber to the marine market, admits that use of chlorinated polyolefin resins will decline both because of price increases and ozone depletion problems associated with the resins' manufacture. According to John D. Pomije, Du Pont market development manager, coatings and resins, Du Pont has introduced the CP 100 series, a family of chlorinated ethylene vinyl acetates with a lower chlorine content. Some resins within the CP 100 series are direct drop-ins for chlorinated rubber, says Pomije. The CP 100 series contains less that 1% carbon tetrachloride, the ozone-depleting component in chlorinated rubber resins, he points out. He expects Du Pont will entirely eliminate the carbon tetrachloride content in the CP 100 series.

Johnson: alkyds, vinyls under pressure

To meet VOC concerns, Du Pont is also developing its chlorinated ethylene vinyl acetate chemistry for use in latex formulations. "It's a high priority program for us," he says. The use of this chemistry in acrylic latex formulation could lead to improved moisture-resistant coatings, he believes. In other developments, Du Pont is working on low-molecular-weight chlorinated polyolefins for incorporation in modified high solids, urethane, and low-VOC epoxy paint systems. The improvement would allow for greater adhesion, flexibility, chemical resistance, and barrier properties, notes Pomije.

Du Pont has still another contribution to the marine paint market. Although it introduced its fluoro-

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chemical additive into the consumer paint market last year for water-resistant outdoor paints, it now says the polytetrafluoroethylene Teflon additive can help produce marine antifoulant coatings. According to Dave D. Silliman, sales and development representative in Du Pont's Polymer Department, the Teflon additive provides a smooth paint surface that impedes barnacle growth. Silliman says in providing a smoother surface, the Teflon additive will also improve vessel speeds. The additive would add to the cost of marine paint, but would allow significant benefits at low loading levels. So the cost increase might be low in a market where paints sell between $100 and $200 a gal.

Powder with a purpose

While marine coating manufacturers are maneuvering to answer a host of new and expected environmentally driven limitations on the products they supply, the powder coatings market would seem to be the most environmentally friendly among reasonable-cost commercial coatings technology. Experts say the transfer efficiency of powder to substrate is on the order of 95%. And because powder is applied as a 100% solids coating, it produces virtually no VOCs. Though many marine structures are too large for the heat-curing technology required in powder coating use, pipe, underhood automotive parts, and metal furniture are ideally suited to powder coatings.

But these coatings are limited almost exclusively to metal substrates. And manufacturers who install powder coating lines generally must completely replace the liquid coating equipment they have already invested in. Further, powder users generally cannot change color on their coating lines as quickly as liquid coatings allow. Powder coatings still make up only 8% of OEM product finishes.

According to Jim Hansen, a spokesman for the Powder Coatings Institute (PCI), the high cost of equipment may once have been a barrier to painters' use of powder, but the cost of equipment has improved considerably and operating costs are comparable to, and perhaps even lower than, liquid coatings. A major impetus for the use of powder coatings is that they admit virtually no air emissions and almost completely eliminate solid waste disposal of used powder. Powder "overspray" can be filtered and recycled.

Overall growth of the powder coatings market in the U.S. has been about 25% annually between 1982 and 1989 when U.S. applicators used 107 million lb of powder, according to PCI data. The institute, made up of powder formulators, material suppliers, and equipment manufacturers, projects 1990 powder sales in the U.S. of 118 million lb and 200 million lb by 1995. Currently, the fastest growing market for powder coatings is in the appliance business, says Hansen, where 22% of all powder is currently used. General metal finishing for patio furniture, office furniture, tool boxes, industrial metal reinforcing rods, pipe linings, and other uses has about 53% of the market, he adds. Another growth market is architectural panels, already a major use in Europe, but currently accounting for only 5% of the U.S. market. Automotive uses account for another 20% of powder coatings applications.

Hans Kuenzel, an industry analyst with Freedonia Group, is also bullish on powder coatings. They can, he says, be applied to metal substrates without primers. And though the cost of upgrading equipment for powder use is a disadvantage and material costs are 8 to 10% higher, high transfer efficiencies and the elimination of almost all waste and emissions offset those costs. Should powder manufacturers be able to lower curing temperatures, powder coatings could find new opportunities in other markets such as plastics, he believes. PCI can confirm a dramatic growth in the number of powder coating suppliers. According to Gregory J. Bocchi, executive director of the institute, about 35 manufacturers and distributors operate today in North America, 22 of whom are currently members of PCI. PCI had only 14 members who were manufacturers or distributors in 1984.

Morton International's Bob Covalt, president of the specialty chemicals group, points out that

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where the market for all coatings overall has been flat in recent years, the market for powder has shown dramatic growth. Morton claims to be the largest U.S. producer of powder coatings. Glidden disputes that claim. Since no producer publishes production numbers, opinion varies as to who is the larger.

Morton arrived at its position in powder through the acquisition of Phillip Morris Industrial, including its Armstrong Powder business. It followed with the purchase of Polymer Corp. from Chesebrough-Pond's, making Morton, says Covalt, the largest U.S. powder coatings supplier.

Covalt acknowledges that the driving force behind the conversion to powder coatings is environmental. Its direct competition is high solid solvent paint and water-borne coatings, he says. Powder, though, is recyclable, largely eliminating waste. And as users have the ability to apply a thin powder film, oven-cured powder coatings make economical and durable product coatings. Where once just a few manufacturers provided powder coatings, "even major liquid coatings formulators who were losing share of market to powder" are now producing powder coatings, he says.

Covalt says Morton supplies customers with polyester, acrylic, epoxy, and nylon powder coatings under its Corvel tradename. The company is backward integrated in the manufacture of polyester resins for powder coatings as it also has a considerable business in the adhesives and sealants business with this resin. Most of the coatings are used in decorative applications such as for metal furniture; lawn and garden equipment; vending machines; and even heating, ventilation, and air-conditioning units for which powder can provide high-grade durable finishes and even thick finishes for corrosion protection.

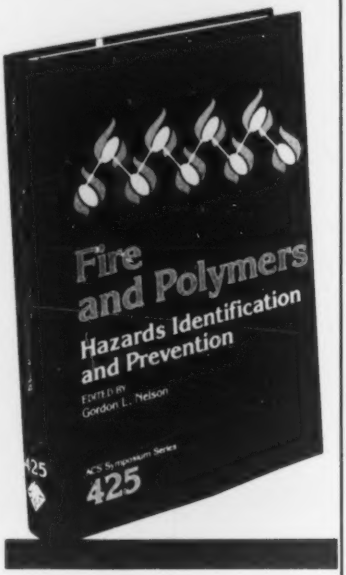
Covalt says some of Morton's epoxy coatings are supplied for use on steel concrete reinforcing rods, or rebar, as well as steel pipe interior coatings. Covalt acknowledges 3M is strongest in this industrial functional applications business. He points out, however, that the decorative coating market for powder is a $300 million market while that for functional coatings is only $75 million.

To date, though, Covalt figures powder probably has only captured about 10% of the market it is eventually likely to capture. "So you can see there is plenty of room for growth," he says. One large market Morton is hoping to see is powder used as an automotive exterior body coating in addition to its use on under-the-hood parts in which powder is already established.

To develop a larger market for automotive powder coatings, Morton has established a new technical service center in Rochester Hills, Mich., to service nearby Detroit auto and automotive parts manufacturers. In addition, Morton recently acquired Whittaker Coatings, a strong player in the liquid coil coatings market. Combined with the Bee Chemical business it also acquired recently, Covalt points out that Morton has a large presence in the automotive market. He says Morton's coating sales is now a $300 million business annually.

Glidden vice president Allen says his company has been involved in powder coatings since the early 1970s. Now that the market for powder in appliances, automotive, and select metal industrial areas is growing, Allen says Glidden is "pleased we stayed there during the lean years." He notes that the powder coatings business has grown from a small base to become a high-performance, low-VOC technology with year-to-year growth rates of at least 12% that continue to make it an attractive business to be in. To fuel further dynamic growth, replace liquid coatings, and increase market share, powder needs a major advance in other large industrial applications. This might be in clear powder top coats, primer surfacers, and antichip coats for automotive body exteriors.

Glidden supplies a full range of powder coatings including epoxy, epoxy-polyester hybrids, polytetraglycidal isocyanate (TGIC), acrylics, and polyester urethanes, says Allen. In addition to metal containers for beer, beverages, and foods, Allen is looking to the use of powder on nonmetallic substrates once lower temperature cures are achieved.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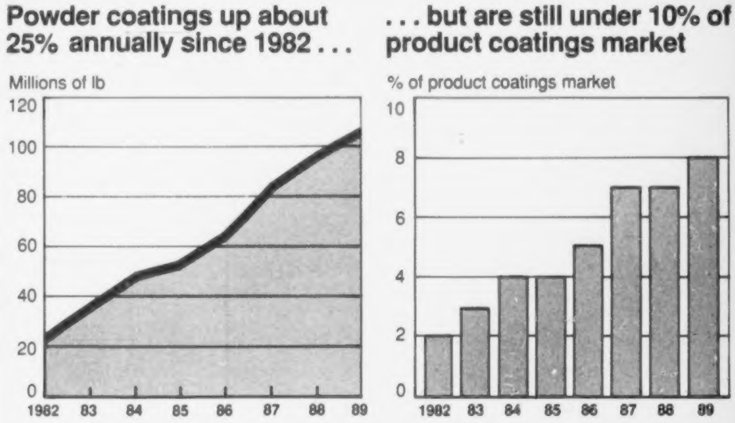

Powder coatings up about 25% annually since 1982 . . .

. . . but are still under 10% of product coatings market

Note: Coatings use as reported by original equipment manufacturers. **Sources:** Bureau of the Census, Powder Coatings Institute, C&EN estimates

Courtaulds Coatings claims to be the "largest and leading powder coating supplier worldwide," says Richard J. Higgins, general manager of the powder coating services group, supplying a broad array of powder coatings under its Interpon tradename including epoxy, epoxy-polyester, and TGIC.

Worldwide, says Higgins, powder coatings have been growing 12 to 15% over the past four to five years. The U.S. didn't seem to exploit the use of powder coatings widely until about five or six years ago. People, he adds, did not seem to expect powder to perform for the long term then. But in Europe, where the environmental advantages of powder were realized much earlier than in the U.S., powder took off, particularly in the U. K. and in Italy, he says, where many coatings applicators were installing new automated lines.

European growth has been dramatic. Where five years ago powder represented about 8% of industrial coatings as a percentage of dry film on the surface of a component, that figure reached 15% in 1989. By 1994, Higgins forecasts that number will reach 18%. In North America, Higgins figures that powder as a percentage of dry film on OEM components was 7% and should grow to 12% by 1994.

One technology for powder coatings that has been developed in South Korea and Japan, and is just being developed in Western Europe and North America, is powder coating of metal blanks. Uncoated metal coil for use in the manufacture of domestic appliances is cut into blanks, to which powder is applied on all surfaces including edges, says Higgins. Once the metal is cured in an oven, it is then folded into shape yielding a metal form that is completely coated, says Higgins.

Another metal coatings market that shows promise to develop further in the U.S. is powder for architectural metal panels. It is more widely used now in Europe than in the U.S., says Higgins. But as powder becomes more widely used in the U.S., that situation should change, he notes.

Powder coating for plastic substrates is under development, says Higgins. Some plastics are now being coated through an in-mold powder coating technique. Also the new generation of high-temperature, high-performance engineering plastics can be powder coated. But current powder coating curing temperatures limit use for general-purpose coatings of plastics, he adds.

However, powder coatings may be applied to more than metal and certain plastic substrates. They may also be applied to glass, roof tiles, and ceramic and clay flower pots. "I don't see an absolute limit to the substrates which powder can coat," says Higgins.

According to Lars Carlson, vice president and general manager of industrial coatings for H. B. Fuller, new powder products are coming into the market constantly. He confirms Higgins' observations that "everyone" is working on applying powder to plastic substrates, and some manufacturers offer powders for in-mold coatings of plastics. Fuller, he says, offers an array of powder coatings including polyesters, urethanes, and hybrids. To keep up with industry growth, Fuller will add a new powder production line in its Chicago facility within the next nine months "in order to handle forecast demand increases," says Carlson. PPG, a supplier of liquid coatings, has more recently become involved as a supplier of powder coatings. Demand for powder coatings depends heavily on environmental pressure, says Gregory C. Wagner, marketing manager of industrial coatings. "Our mission is to sell what the customer needs," says Wagner, citing PPG's ability to supply electrodeposition, high solids, water-thinned, and radiation-cured coatings as well. PPG supplies a number of powder types from resins it manufactures including polyester, epoxy, acrylics, and hybrids under its Enviracryl tradename. Applications are mostly for decorative metal surfaces.

However, PPG has begun supplying some powder coatings for plastic substrates. Wagner says the company has been selling powders for sheet-molding compound, a fiberglass plastic composite widely used for automotive body panels, for about a year. "We have powder products that cure at temperatures as low as 250 °F," he says.

According to Debra E. Gill, national product manager for the powder coatings division of O'Brien Corp., manufacturer of Fuller O'Brien paints, powder coatings will continue to improve with thin, smooth films achieving extended weatherability. Developments are continuing in powder coatings for plastic components and "possibly wood where low-temperature powder coatings will be employed." She adds that "conductive coatings are on the horizon."

3M's Scotchkote powder epoxy powder coatings business is aimed at markets for pipeline and reinforcing steel protective coatings. Its Scotchcast powder epoxys are formulated for use as electrical insulation for products such as motor stators and armatures. It had been involved with powder coatings for 30 years when, says Tom McDonnell, program manager for the electrical products division, "3M pioneered the development of fusion epoxy resins as pipe coatings." Today, 3M's epoxy powders "fit most every need in the functional coatings area. By design, 3M does not participate in the decorative resin market," he adds.

Domestic growth of 3M's powder business depends on the business cycle in the pipeline industry and in structural and reinforcing steel "if federal and state highway construction funds are available," says McDonnell. He admits 3M has not been as forward with its epoxy powders outside the North American market, and, as a result, "expects the majority of its growth to be in foreign mar-

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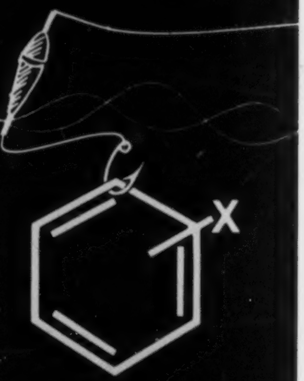

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kets where this proven technology can be adapted locally."

American Cyanamid, a material supplier to powder coatings formulators, says it has a new amino crosslinker that may well yield a new class of lower cure powder coatings than now exist. It has been gearing up to produce its Powderlink 1174, says Charles Van Fleet, resin products department project manager, commercial quantities of which will be available in the fourth quarter of this year. Conveyors and flakers are now being installed at Cyanamid's major amino resins plant in Wallingford, Conn., to handle and isolate the amino solids needed to manufacture Powderlink 1174. Van Fleet could not say what actual capacity of the resin would be, but said that Cyanamid would be able to supply "hundreds of thousands of pounds."

Powderlink 1174 is partly an answer to toxicity concerns with TGIC powder coats as they cure. It also provides an economic incentive for users in that they will be able to formulate a coating using hydroxyl rather than carboxyl polyester. Van Fleet says Powderlink 1174 has a formaldehyde level below 0.1%, and notes, "the predominant product of reaction is methanol." Using the new product would lower powder coatings raw material costs 15 to 20%, says Van Fleet.

In addition, Cyanamid has isolated a new catalyst, methyltolylsulfonimide (MTSI) for use in conjunction with its Powderlink resin for high-gloss films. However, that product is not commercially available. Van Fleet, though, says Ruco Polymer Corp., formerly part of Occidental Chemical, manufactures a polyester resin that contains catalyst functionality and can provide powder coatings manufacturers with a product whose exterior durability is competitive with current top coats and can compete in appearance with urethane-type coatings. Van Fleet believes that powder coatings containing the new Powderlink product will find their way to the general industrial applications market including patio furniture, office furniture, appliances, and even architectural coatings.

Another material supplier taking aim at TGIC's toxicity problem is Rohm & Haas. According to Herb Pigrom, powder coatings market manager, his company has introduced a new crosslinker, Primid XL-552. He describes it as a hydroxyalkamide that together with a carboxyl polyester resin will yield a very durable resin. Rohm & Haas claims powders manufactured using its new crosslinker will have better hardness, and scratch and detergent resistance than current powders.

Dow Chemical's Kip Thomson, powder coatings marketing manager, says his company is a major supplier of epoxy resins and phenolic hardeners for powder coatings producers. He believes epoxy hybrid powders are faster growing than straight epoxy formulas. Among resin systems, he ranks hybrids such as epoxy-polyesters first, followed by TGIC, polyurethane, and straight epoxy systems. Dow plans to commercialize an epoxy resin for use in conjunction with a polyester, with the experimental designation of XU 71863.01 within the next few months, he says.

Michael Chovan, specialty products manager for carboxyl and hydroxyl polyester resin producer Cargill, says his company is helping customers to develop clear powder coats for doors, faucets, and kitchen sinks, among other applications. However, he believes the business slowdown now under way will slow powder sales growth overall in 1990 to 10 to 12% for the year.

Paint disposal issues loom

While powder coatings boast minimal waste produced in the applications process, all liquid-applied spray coatings are subject to transfer efficiency limits of 50% at best. Used in an industrial setting, the overspray clogs grates, interferes with spray booth airflows, and must be separated and disposed of. These problems may argue for greater use of alternative technologies like powder. But because of the heavy investment in liquid spray technology, its long-term proven performance, and the work of water treatment companies, overspray is becoming less of a problem.

In fact, sludge captured from

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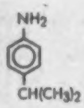
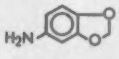
4-Isopropylaniline
(4-Aminocumene)

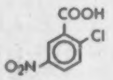


3,4-Methylenedioxyaniline
and N-Ethyl derivative

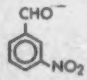


2,3-Benzofuran
(Coumarone)

2-Chloro-5-nitrobenzoic acid



3-Nitrobenzaldehyde



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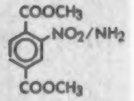

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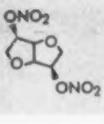

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paint overspray is an issue the water treatment companies and their customers are attempting to deal with before legislation forcing a solution comes into effect. After all, the industry only has to follow the crazy quilt of varying nationwide VOC standards to see what can happen when government gets involved with imposing solutions. In the case of overspray clean-out and subsequent careful sludge disposal or recycling, economic efficiencies require both more efficient spray booth operation and disposal techniques that will not come back to haunt waste generators.

According to Ed Kliff, vice president of chemical industry consultants Phillip Townsend Associates, the current size of the market for chemicals, emulsions, and services to treat paint overspray is about $50 million. It is potentially at least four times as large and perhaps many times larger when industrial spray booth operations other than automotive, the largest segment, are added in, he says.

Chuck Zuerner, market development manager for Nalco's HEC Management Services, says aside from the automotive paint overspray market, paint overspray treatment markets could also include aircraft or bicycle wet spray paint lines. Anyone who operates a wet spray booth could benefit from Nalco's water treatment chemistry, he notes. Nalco is now promoting its management services in which HEC supervises the treatment of overspray in the booth, its clean-out and disposal. Nalco's people are at the spray booth site full time, says Zuerner, supervising the addition of the company oil and water emulsion in the paint spray booth water.

Nalco's HEC Services contracts with RTR's vacuum trucks to remove its sludge and haul it to an RTR facility where a Nalco-supplied oil is separated from the sludge and reclaimed for later use and the solids are supplied to cement kiln operators as a filler and fuel supplement. Ash from the paint pigment fuses with the cement aggregate to form a neutral filler, says Zuerner. "Our niche is with companies who were landfilling their paint sludge as a hazardous waste." Other benefits are a cleaner spray booth and reduced clean-out labor, adds Zuerner.

Zuerner says the HEC system also requires a closed system to preclude overflow of toxic organics in paint into municipal sewer systems as well as a mist elimination system to reduce residual spray solids that could be vented from the booth air exhausts. The mist elimination system poses benefits particularly where a spray operation may be close to a residential area. Neighbors are not too pleased with paint residue that may settle around their homes, he notes.

According to Jim Marcrum, director of Calgon Water Management's Interac Group, the company's new Paint Kill system offers to isolate 30 to 40% dry solids using Calgon chemistry as opposed to 15% solids in older systems. With less water to evaporate from the solids, less drying energy is required. Marcrum says the company uses all polymer chemistry to increase solids capture as opposed to other systems that use aluminum, iron, zinc salts, or bentonite clay and only then use polymers to flocculate the paint solids.

As a result of Calgon's water treatment efficiency, Marcrum says pit and plenum clean-out is greatly reduced. One customer adapted the system and was able to reduce its paint spray booth clean-out schedule from every four weeks to once every six months. Marcrum also claims the new Paint Kill system allows per-unit treatment at $1.50 while competing detackification systems cost between $3.50 and $6.00 per comparable unit.

Historically the wet cake sludge is landfilled. In most cases it is not classified as hazardous, says Marcrum. But Calgon is working now with a paint manufacturer to dry the sludge to a 99% dry powder and recycle it into a paint. The dry sludge might also be used as a filler in adhesive formulations, he suggests.

Gary A. Tonn, business development manager with W. R. Grace's Dearborn division, says his company can also offer all-polymer chemistry to isolate and detackify paint overspray in booth operations. Tonn says Dearborn's chemistry can detackify some otherwise hard to treat, low-VOC, high-solids paints. Once the paint solids are isolated from the booth water, that water is "very clean," has very few suspended solids, and can be recirculated in the spray booth. "Though we supply and provide service support, the plant people generally make the chemical additions to the booth water. Though in one plant we do control the chemical treatment program," he says.

Sludge resulting from the water treatment is dried, says Tonn, and is landfilled or used in cement kiln operations. While the customer generally disposes of the sludge, Tonn says Grace's Dewey & Almy Teroson automotive experts are working with consolidated and dried paint sludge for use as an inert filler in underbody coatings and sealers including epoxy adhesives. They are in the process of scaling up a commercial process plant and have already proved that the incorporation of the sludge into these products meets test specifications. Where they use the sludge for their products, Dewey & Almy would purchase it from the paint booth operator.

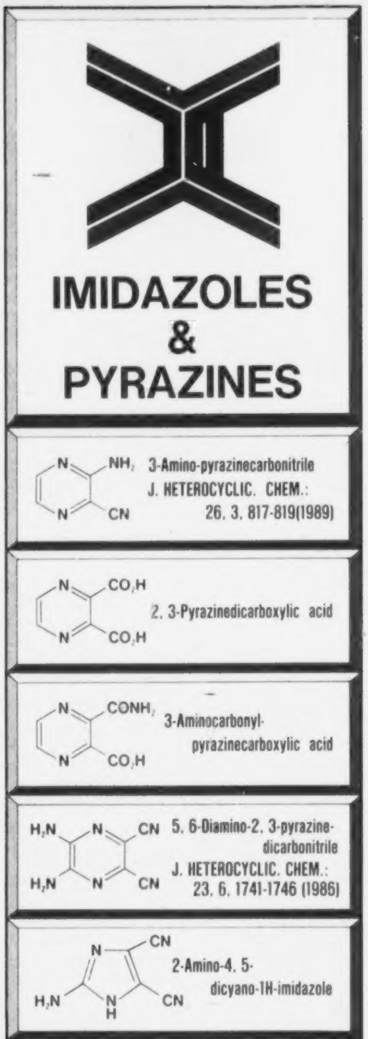
Carmen Sarno, vice president of technical marketing at Betz Lab's Metchem division says his company provides customers with a complete program of polymers, antifoams, biocides, and auxilliary products for the maintenance of a clean spray booth. Most customers are in the general manufacturing and automotive business. Each customer receives a customized program to help in efficient booth operation allowing for the greatest transfer efficiency of paint spray operations. He adds that "we're spending a lot of research and engineering time on developing detackification programs for water-based paints. Our customers are all looking at it. It's coming."

Allen: powder on nonmetallics soon

Thomson: epoxy hybrids growing fast

According to Kenneth J. Lehman, business vice president of Henkel's Parker Amchem subsidiary, this large supplier of phosphate treatments for steel is now investigating systems to reduce sludge produced in the phosphating process. Phosphate sludge now either goes through a sediment filter or is skimmed off like paint sludge and landfilled as a nonhazardous waste, he says. The company is attempting to perfect treatments with as high a solids content as possible.

Parker Amchem also supplies defoamers, deflocculants, and biocides to spray booth operators, says Lehman. Here, too, the aim is to bring the solids content up as high as possible. Parker Amchem contracts with other suppliers to haul paint sludge away from its customers' operations to a landfill, but it is working on programs to recycle the sludge, possibly as a filler for a sound- deadening coating or for incineration. □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3-Amino-pyrazinecarbonitrile
J. HETEROCYCLIC. CHEM.: 26, 3, 817-819(1989)

2, 3-Pyrazinedicarboxylic acid

3-Aminocarbonyl-pyrazinecarboxylic acid

5, 6-Diamino-2, 3-pyrazine-dicarbonitrile
J. HETEROCYCLIC. CHEM.: 23, 6, 1741-1746 (1986)

2-Amino-4, 5-dicyano-1H-imidazole

5-Amino-1H-imidazole-4-carbonitrile

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Candidates in ACS fall election:
Their views and backgrounds
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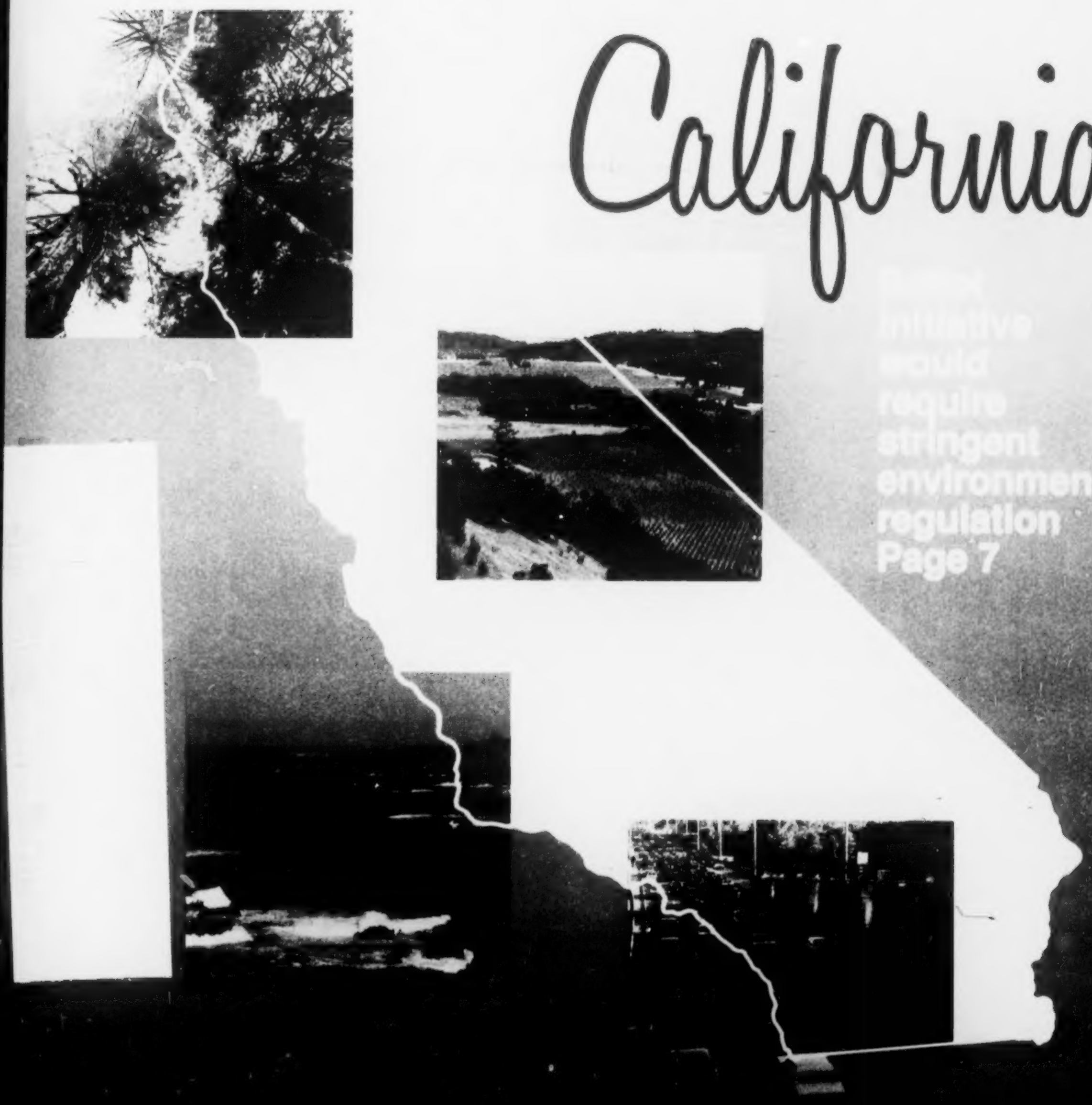

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SEPTEMBER 24, 1990

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- **Forecast for 1990 chemical capital spending is revised downward in the latest Commerce Department survey.** Page 5
- **Researchers discover way to genetically modify defective cystic fibrosis cells and so open opportunity for future gene therapy.** Page 5
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LETTERS

Biomass burning

Your "News of the Week" article (C&EN, March 26, page 4) claims that the environment is hurt more than thought by biomass burning.

This view arose from the atmospheric sciences' attempting to model the fate of fire-released gases in the environment. The conclusion reached may be wrong.

Many plants are serotinous; that is, their seeds are opened and released only by fire. Indeed, some 90,000 hectares of southwestern Africa possess a unique biome of some 8000 species, known as "fynbos," which relies almost totally on fire for its propagation. Far from hurting the environment, fire is an essential component.

William H. Romme and Don G. Despain [*Sci. Am.*, **261**, 36 (1989)] document the effects of burning Yellowstone in 1988. Massive fires every 150 years or so are part of the natural succession of the woodlands, not only propagating serotinous species but also releasing a range of essential nutrients. Indeed, evidence is accumulating that the alkaline ash generated in fires is an essential component in neutralizing acidity generated in leaf decay, particularly in conifer forests, and may help to protect woodlands against acid rain.

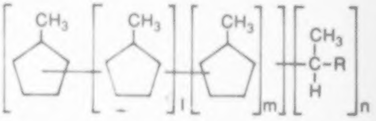
Although I am sure there is merit in being concerned about the buildup of carbon dioxide in the atmosphere, I am also concerned that dramatic headlines such as your own may cause precipitate action against biomass burning and result in more harm to the environment than good. The atmospheric modelers must take into account the essential natural contribution of fire.

Philip J. Lloyd
Industrial & Petrochemical Consultants, Ravenmoor
South Africa

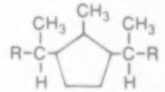
Alkylated cyclopentanes

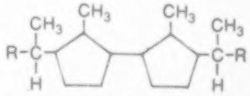
Please refer to Joseph Haggin's comments (C&EN, May 2, page 60) on a "new class of synthetic lubricants for extreme service conditions"—the alkylated cyclopentanes, presented recently by two chemists of Pennzoil Products Co. at the ACS national meeting in Boston.

The synthesis and the good properties of the alkylated cyclopentane oils were discovered in my laboratory in 1957 at the Research Department of Imperial Oil Ltd., Sarnia, Ontario. This invention is demonstrated in my patents: U.S. No. 3,000,981 and Canadian No. 655,942. The synthesis consists of alkylating monochlorinated methylcyclopentane with *n*-1-olefins in the presence of a Friedel-Crafts catalyst followed by hydrogenation over nickel to remove chlorine. The resultant oil was obtained in good yield and had good viscometric properties and low-temperature fluidity. For example, alkylation with *n*-1-decene gave an oil having a viscosity index of 131, a viscosity of 5.64 centistokes at 98.9 °C, and a pour point of -57 °C. The synthesis is very diversified, due to the numerous parameters involved, so that the following general formula was envisaged based on NMR data



where l, m, n are integers and R is a linear saturated hydrocarbon chain having a number of carbon atoms equal to that of the *n*-1-olefin used minus two. The following shows an example of two of the several structures obtained by this process:





I should mention that my work on this subject was triggered by the American Petroleum Institute reports on good viscometric and low-temperature properties of certain pure hydrocarbon compounds incorporating cyclopentane.

Dimitrios V. Favis
Beaconsfield, Quebec

Correction

- Aug. 27, page 17: The man pictured is Robert M. White, National Academy of Engineering president, not Robert M. White, Commerce undersecretary for technology, quoted in the story.

Promising New Markets Emerging For Commercial Enzymes

Potential uses for enzymes, whose growth has slowed recently, include animal feed additive, pulp bleaching, "biostoning" of denim

Detergents, dairy processing, and starch conversion: the classic major markets for enzymes. But new applications opening up, and other potential uses, are expanding the field for commercial enzymes beyond those traditional applications. The keys to some of the newest uses of enzymes: gentle biological action to replace rough mechanical action, in at least one new area, and more broadly, the capabilities to alleviate some environmental problems.

Those are among the conclusions of a new study of the $650 million enzymes business by London-based consultants L. Hepner & Associates. The study focuses on some 21 enzymes of industrial importance, which Leo Hepner and his colleague Celia Male define as those materials accounting for minimum annual sales of $1 million, in an industry that has been growing at about 10% per year. But it is also an industry that has slowed and that promises only basic growth of 3 to 4% per year over the next five years.

The enzyme-using markets were also examined: the traditional markets of detergents, starch conversion, and dairy, which together consume about 80% of all industrial enzymes, both merchant and captive, and a raft of smaller uses. These smaller uses cover a variety of industries, such as beverages; textile and leather treatments; food applications; animal feeds and silage; antibiotics and amino acids; and paper and pulp processing. Each of these uses currently accounts for anywhere from $1 million up to $30 million. The consultants also picked out promising new applications, including expanded uses in animal feed and in pulp and paper processing.

For some applications that might be suitable for enzymes, there is an appropriate material available, but at an inordinate price. That brings Hepner and Male to another focus of their study, improved technological capabilities in biotechnology, including protein engineering and recombinant technology.

Four years ago, according to the study, such work was still an academic exercise. However, there are now commercial products. A case in point is chymosin, a replacement for microbial rennin, in turn a replacement for calf rennin for cheese.

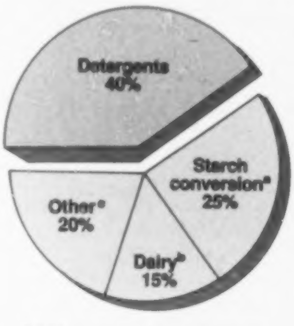
One of the most novel applications the study identified is for phytase as an animal feed additive. Phytin in grain binds phosphate, needed for bone development, in the feed. The feed formulator must dose the grain with additional phosphate so enough is available to the growing animal. An excess passes through in the animal's excrement, contributing to phosphate pollution in water. However, if a formulator pretreats feeds with phytase, the bound phosphate is released for metabolization. That dramatically reduces the need for additional phosphate dosing, and, in turn, lessens the pollution problem.

Enzymes stand to find a market solving yet another environmental problem, say the consultants, in bleaching of pulp. In the pulping process, cellulose is pretreated with calcium sulfite to digest wood chips. But lignin is left in the fiber; for bright white paper, bleaching is necessary. Lignin is shielded with a hemicellulose coating, so an excess of chlorine must be used for bleaching. However, if the hemicellulose is removed with cellulase or hemicellulase, the chlorine needed can be significantly reduced, thus lowering its presence in effluent.

A number of paper mills are now running trials, but chlorine is cheap, and cellulase would have to cost less than $5.00 per ton of pulp, without subsidies, to be competitive. However, the potential for this application is huge: There are some 50 million metric tons of bleached pulp made worldwide each year.

In a more fashion-conscious application, a cellulase formulation has been introduced for "biostoning," to vie with mechanical stone-washing of denim garments. In the U.S., about 50% of denim garments are stone-washed; in Western Europe, 70%. Pumice is typically used, added into industrial laundry machines with jeans, to rub against the fabric and remove some of the dye. But too

Detergents continue to dominate enzyme markets



1989 sales = $650 million

a Glucose, ethanol, and high-fructose corn syrups. b Rennin and others. c Includes fruit juice and other beverages; baking and flour; food additives; textiles and leather; and pulp and paper. **Source:** L. Hepner & Associates much abrasion can damage the fabric. "Biostoning" features enzymes rather than pumice. According to Danish producer Novo Nordisk, the largest enzyme supplier worldwide, a cupful of enzyme could replace 100 times its weight in pumice stones.

Ironically, the development of cellulase markets points out one of the problems attendant to the enzymes industry: commodity versus specialty. The trick is to tailor enzymes for specific customer needs, a demand that is slowly leading to a decline in the number of suppliers. Small to medium-size companies are being snapped up by larger ones, as the market consolidates.

The number of major producers is now down to about 10, led by Novo Nordisk. Others include Gist Brocades, of the Netherlands; the Gist Brocades-Shell joint venture, IBIS; Cultor, formerly Finnish Sugar Co.; and Cultor's joint venture with Eastman Kodak, Genencor International.

Earlier this year Solvay bought part of the enzymes business of Bayer's Miles subsidiary to add to its Kali Chemie enzymes business. Another part of the Miles operations went to Rhône-Poulenc, now number two in dairy enzymes (Denmark's Hansen is number one). Other major enzyme makers are Unilever's Quest unit, which bought Biocon Biochemicals, a small Irish producer of brewing enzymes, and Sturge, with the citric acid and enzymes it acquired from RTZ, which recently shed its chemical operations.

The captive market currently accounts for 10% of enzyme consumption, led by Archer Daniels Midland of the U.S., for starch conversion for high-fructose corn syrup, and Henkel of West Germany for detergent proteases.

Detergent enzymes are also of particular interest for Japanese producers. The Japanese supply a market worth from $50 million to $60 million and that has probably doubled over the past four years, the study estimates. Part of the market is accounted for by traditional enzymes, for uses such as starch conversion and proteases.

Other, more unusual enzymes find applications in the Japanese market, too. For example, Japanese detergent producers use a cellulase in their no-builder concentrated detergent. And development is also being done on amylase, for formulating into dishwashing detergents as starch solubilizers.

The growth rate of the enzyme industry has been 10% per year over the past few years, but falling prices have brought an end to those days, the study says. Instead, it assumes a basic growth rate of 3 to 4% per year for the traditional markets over the next five years.

If some of the potential uses materialize, such as proteases penetrating further into the detergent market, or recombinant chymosin replacing microbial rennin, or phytase being used as a feed additive, total sales could rise more rapidly. Moreover, the market for cellulases and hemicellulases for pulp and paper could hit $200 million in five to 10 years, the study predicts.

"If all these things happen, growth could be 12% per year, taking the business to $1 billion by 1995," Hepner points out. However, Male cautions, "Some of these markets may not materialize: The enzymes may be too expensive, there may be a backlash against genetically engineered enzymes, and so on. Then the base growth of 3 to 4% per year will bring sales to about $750 million by five years."

The study also predicts that small enzyme producers, those with sales of less than $10 million per year, probably are not viable. Smaller companies, Hepner believes, cannot afford the time it takes—often 10 years—to develop a new market, such as that for cellulase. A producer could find a specific niche, he concedes, but "would still have to have the resources to make the enzymes, or to market them." Possible solutions might include a link with a producer who could make the enzymes for the company, or a link with a consortium of customers—several pulp makers, for example.

Patricia Layman

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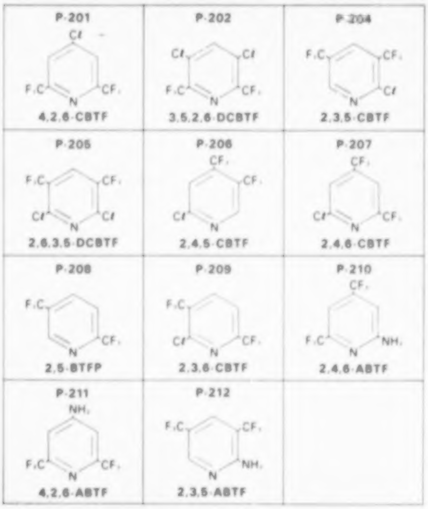

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CHEMICAL & ENGINEERING NEWS

Symposium focuses on key role of electron transfer in chemistry
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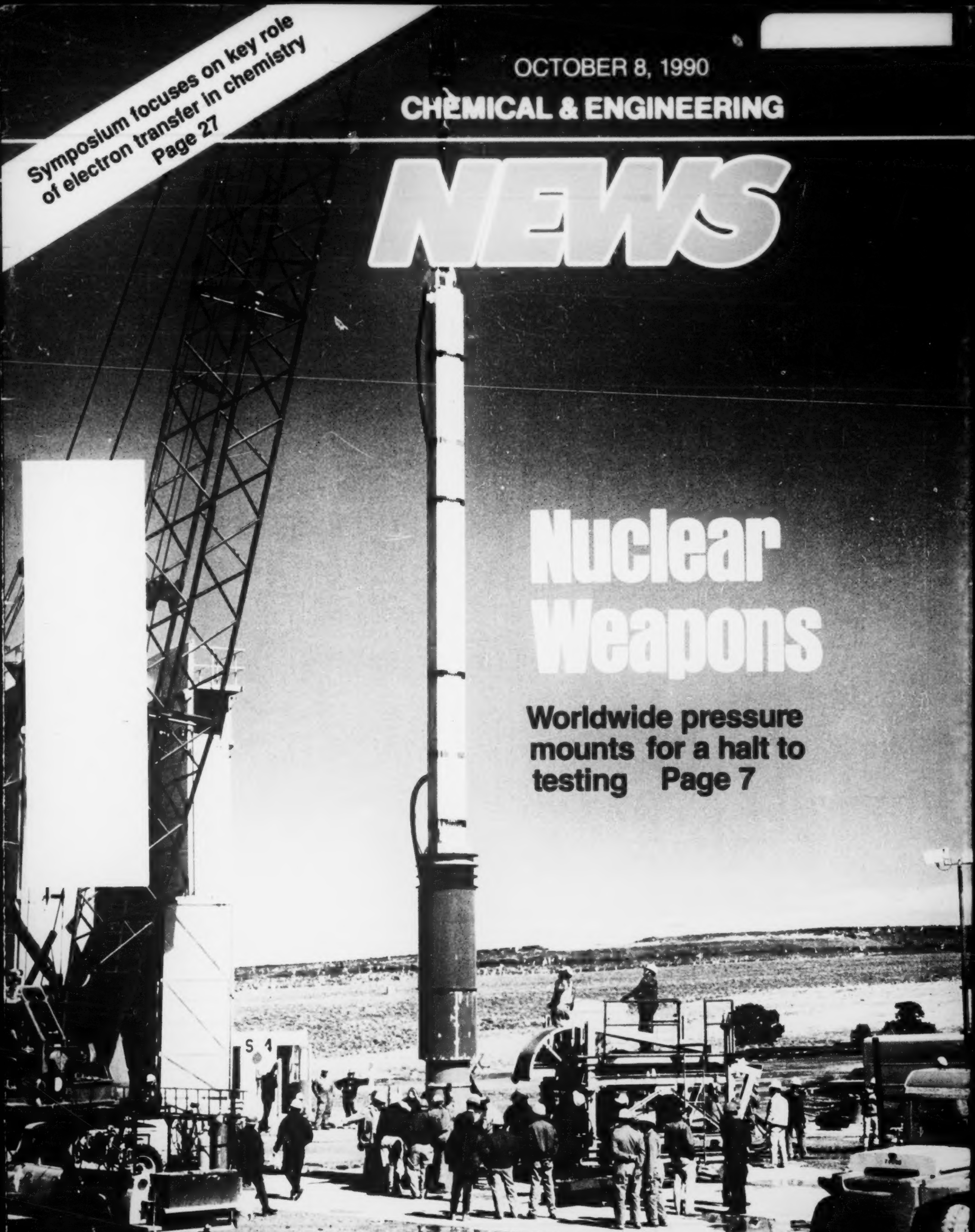

Nuclear Weapons

Worldwide pressure mounts for a halt to testing Page 7

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CHEMICAL & ENGINEERING NEWS

OCTOBER 8, 1990

News of the Week

■ **Soviet chemical industry appears to be in for slow or no growth or even contraction, as it reflects that nation's serious economic crisis.** **Page 4**

■ **National Academy of Engineering president decries "excesses" within the U.S. scientific community.** **Page 5**

■ **Compromise federal budget pact is expected to have little impact on science R&D funding or on the chemical industry.** **Page 5**

■ **Du Pont chairman takes dramatic steps to change firm's management structure.** **Page 6**

■ **British researchers invent simple and inexpensive way to make tough and crack-resistant ceramics.** **Page 6**

Business

Canadian chemical firms may garner uneven benefits from European Community's planned move to a single market by 1992. **Page 14**

U.K.'s Dextra Laboratories is enjoying—and being recognized for—its success in carbohydrate research. **Page 17**

Chlor-alkali industry discusses changing market, technological innovations, environmental issues during recent symposium. **Page 18**

Linear α-olefins market is expected to show good growth prospects during the early part of the decade. **Page 20**

Government

Allocation of more funds to training young scientists, improving research facilities called for by Institute of Medicine study. **Page 22**

Science/Technology

Progress in research on electron transfer highlighted at recent ACS symposium. **Page 27**

Plutonium finds unlikely use as probe in superconductor and protein studies. **Page 32**

Two Japanese pharmaceutical firms to establish basic research units in U.K. **Page 33**

Cover: Workers prepare to test nuclear weapon at government's Yucca Flat, Nev., testing site. Photo courtesy of Department of Energy

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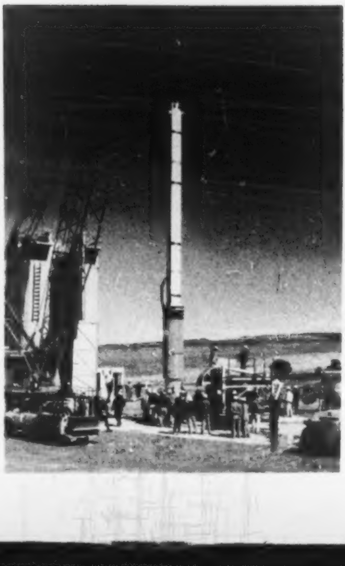

News Focus

The thorny issue of nuclear weapons testing exacerbates sovereignty, other dilemmas in the U.S.S.R. and causes problems for a treaty to halt the spread of nuclear arms, with U.S. opposed to a total ban. **Page 7**

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LETTERS

Science education

The report, "Winds of Revolution Sweep through Science Education" (C&EN, June 11, page 27), is excellent, but the major restructurings reported are at best a good beginning. The problems of education cannot be solved to any degree just by change in the classroom, as it is only one variable. There are others, the most important of which is the cluster of attitudes that American society has about education. These attitudes are so important that, if they are not changed, they will substantially reduce the effect of other changes.

This is not to say that we should not go ahead with restructurings. But there needs to be a simultaneous effort to upgrade the perceived value of education. This is the biggest advantage that the Japanese have. They think education is important. Few Americans do to the extent that the Japanese do.

E. G. Sherburne Jr.
President, Science Service
Washington, D.C.

Thermodynamic equation

My purpose in writing this letter is to describe some fun I had with a thermodynamic equation after it was reported (C&EN, Oct. 9, 1989, page 23) that Spectra brand polyethylene melts at 147 °C, "which cannot be significantly improved because it is an inherent property."

Years ago I was interested in relating the solubility of the highly *n*-paraffinic waxes present in No. 2 diesel and domestic burner fuels to the total composition of these fuels. Upon cooling, these fuels solidify when only a small amount of wax has precipitated, unless a wax modifier is present. I assumed that these fuels were essentially ideal solutions of *n*-paraffin mixtures in liquid hydrocarbon solvent phases, and that enthalpy and entropy of fusion of the precipitating wax were linear functions of the number average molecular weight of the *n*-paraffins in this wax. (For individual *n*-paraffins, enthalpy and entropy of fusion are linear functions of molecular weight.)

Thus:

$$\log W = a + bM + (c + dM)/T$$

Here W is the mole fraction of *n*-paraffins of M number average molecular weight present in a fuel with an observed wax cloud point of T degrees absolute. Fuels were studied in sets of four to evaluate constants a, b, c, and d in simultaneous equations. M was calculated from gas chromatography analysis of the wax filtered off at about 20 °C below the cloud point, and the molecular weight of the liquid phase (filtrate) was obtained by any of the usual methods, such as ebulliometry. It was found that the assumptions were tenable and that:

$$\log W = 2.63449 + 2.48608 \times 10^{-2}M - 10.4107M/T$$

(These constants provide for a change from natural logarithms to base 10, and the gas constant R is included in the last term. Dimensions will be obvious. Constant c was so small that it could be set equal to zero.)

This equation was found to work for petroleum hydrocarbon fuels varying widely in composition and properties.

But this is not the point of my letter.

I applied this equation to polyethylene resin by letting W = 1, (log W = 0) and dividing by M (letting $M = \infty$). At $M = \infty$, T will be the highest melting point possible as predicted by this equation.

$$\log W/M = 2.63449/M + 2.48608 \times 10^{-2}M/M - 10.4107M/MT$$

$$0 = 0.00000 + 2.48608 \times 10^{-2} - 10.4107/T$$

Solving: T = 418.8 K, or T = 145.6 °C

The value of 147 °C must have been calculated in some similar way, but it seems unreasonable to expect an extrapolation to work from several chemically rather untidy, low molecular weight (200 to 400), dilute solutions, all the way up to a pure, very high molecular weight (1,000,000 to 5,000,000), highly crystalline solid. But it does work rather well. To those who are more adept at thermodynamics than I, it may be obvious that the limiting melting point of polyethylene should be given by the ratio of constant d to constant b, but this was an exciting discovery for me.

Perhaps more recent generations of chemists prefer more sophisticated types of investigation, but I am not apologetic about my enthusiasm for the type just described. This kind of discovery every once in a while made my work as a chemist interesting and worthwhile.

Scientists cannot have complete control over their opportunities for creativity and invention, and there is not always provision for subsequent monetary bonuses for success in these areas. However, I am convinced that anyone who likes math and science is sure to find such opportunities in chemistry. There will be rewards, and each opportunity will be an important part of these rewards.

William C. Hollyday Jr.
Watchung, N.J.

Canadian Firms May Reap Uneven Benefits from EC's 1992 Plan

Biotech, generic drug, and specialty chemicals industries likely to be among winners but commodity chemicals, others may struggle to hold steady

Earl V. Anderson,
C&EN Northeast News Bureau

The European Community's sweeping plan to remove internal trade barriers among member countries and to create a harmonized European market by the end of 1992 will lead to the largest single integrated market in the world. It will have an impact on Canadian chemical companies, just as it will on every other chemical firm inside and outside the EC.

But the impact will not fall equally on all Canadian chemical companies. Some may benefit, and others may be hurt, depending on each company's circumstances.

That, at least, is the gist of a report recently issued by the government agency, External Affairs & International Trade Canada. The report, "1992 Implications of a Single European Market," covers chemicals, new materials, pharmaceuticals, and biotechnology. It is one of several EAITC has issued on the EC's 1992 plan over the past year and a half.

The products—and the companies—that the EAITC report covers are extremely diverse. Nevertheless, say its authors, they have been able to develop some general conclusions. For instance, how well many Canadian chemical companies will be able to exploit the opportunities that the European market will provide may well be linked to how successfully they have responded to the opportunities provided by the Canada-U.S. free trade agreement. Those chemical companies that have increased their scale of operations to take advantage of markets in the U.S. as well as in Canada probably will find it easier to crack the new European market.

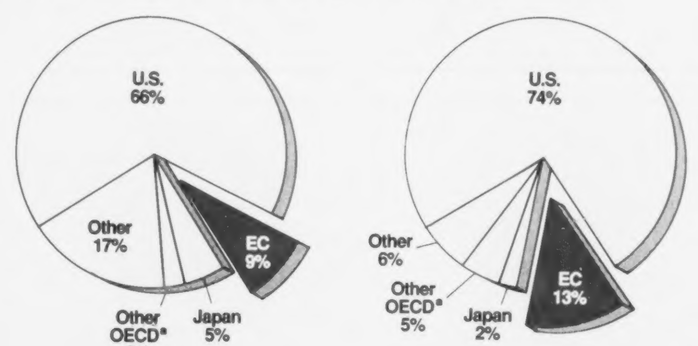
Much will depend, too, upon whether a Canadian chemical company already does business in Europe and whether that business involves direct investment or exports. Even those companies that do not trade with Europe now will feel the sting of a united European market. That's because, as European competitors become stronger from the growth that a single European market is expected to create, they will use their newfound strength to expand into other markets, including those in North America.

Right now, Canada's biggest chemical trading partner is the U.S. The EC is not much of a factor. Last year, Canada exported $6.2 billion worth of chemicals (at current exchange rates). Two thirds of that went to the U.S. Only $544 million worth, or 8.7%, was shipped to the EC. Even Asia, including Japan, is a much more important market for Canadian chemical exports.

But that 8.7% average can be misleading. For some chemical categories—particularly for synthetic rubber, plastics, and plastics products—exports to the EC are a much lower percentage of the total. Canadian chemical exports that far exceed the average include organic chemicals, at 16.3%.

The story is the same for Canadian chemical imports. Canada imported slightly more than $7 billion in chemicals last year, with almost 74% of it coming from the U.S. The EC shipped only $938 million worth of chemicals to Canada, or about 13% of Canada's total chemical imports.

Canadian trade with European Community is small



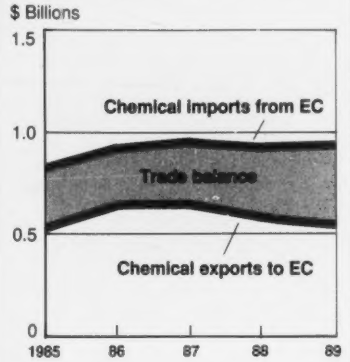
1989 Canadian chemical exports = $6.22 billion

1989 Canadian chemical imports = $7.06 billion

a Members of the Organization for Economic Cooperation & Development, except the U.S., Japan, and members of the EC.
Source: Statistics Canada

For some chemical products, however, the EC is a significant supplier to Canada. For instance, a hefty 49% of Canada's dye imports came from

Canada's chemical trade deficit with EC persists



Source: Statistics Canada

the EC last year, as did almost 30% of Canada's imports of pigments, "lakes," and toners. The EC also accounted for 22% of the country's organic chemical imports.

The large commodity chemical firms operating in Canada, such as Nova, Dow Chemical, Du Pont, Union Carbide, and ICI, all have plants in the EC. So do some of the large multinational pharmaceutical companies, such as American Home Products, Merck Frosst, and Johnson & Johnson. Because their EC subsidiaries qualify as "EC companies," they are likely to benefit directly from the more liberal trade conditions of the new European market. Many multinational chemical companies in Canada note, for instance, that the integrated EC likely will make it easier for them to move products across country borders within the EC. Packaging and labeling requirements also are likely to be simplified.

Certainly those Canadian companies with EC subsidiaries probably will benefit more from the EC plan than the firms that only export to the EC, says EAITC. One reason: They will have better access to information about their markets. And they will be in a better position to influence EC product standards and other EC policy matters.

Exactly how much the Canadian subsidiaries of the large commodity multinationals will benefit depends on the decisions their multinational parents make. It is they who will decide how much of their EC market requirements will be produced in Canada. It is they who will decide how much will be produced in the EC—or somewhere else.

For the commodity chemicals producer in Canada, EAITC doesn't expect a more unified European market to yield dramatic improvements. Much of the feedstock and energy advantages that Canadian producers once had have evaporated (although the Mideast crisis could quickly reverse this). Meanwhile, these companies are still adapting to the U.S.-Canada free trade agreement and the larger U.S. market that it brings. This will command their attention for some time yet.

The Pacific Rim also has become a much more important export market for these companies, and it could become even more important. Even within Canada, some important chemical markets are growing and could loom more important than the EC market. The pulp and paper industry is one example.

Consequently, Canadian producers of commodity chemicals probably won't be hurt by the upcoming market in Europe. They may even benefit a little. But the 1992 plan won't divert much of Canada's commodity chemical trade to Europe. Canadian producers enjoy a bigger advantage in other world markets.

The specialty chemicals segment of the Canadian industry, however, may find more opportunities for profitable niches from the European 1992 plan than its present weakness suggests. Certainly it faces many obstacles. Canada runs a massive trade deficit in specialties. European chemical firms are very strong international competitors, and they continue to invest heavily in specialties. Because of Canada's relatively weak pharmaceutical industry, fine chemicals production is negligible. There's little incentive to develop a larger production base. However, things could change for Canada's specialty chemical producers. The trade agreement with the U.S. may make it possible for them to increase their scale of operations and, in the process, become stronger international competitors. Although they are few, some already do sell in Europe. And a few multinationals al-

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ready have given the go-ahead to their Canadian subsidiaries to produce specialties for world markets. Du Pont Canada's specialty resins are an example.

EC receives less than 9% of Canadian chemical exports

$ Millions[a]	1989 Canadian chemical exports		
	Total	To EC	% EC
Chemical elements	$ 174.8	$ 29.9	17.1%
Other inorganics	1141.7	96.5	8.5
Organics	1582.0	258.2	16.3
Fertilizer & fertilizer materials	1269.5	56.5	4.5
Synthetic rubber & plastic materials	1206.6	57.0	4.7
Plastic basic shapes & forms	414.4	8.8	2.1
Other chemicals	434.0	37.2	8.6
TOTAL	**$6223.0**	**$544.1**	**8.7%**

[a] U.S. dollars, converted from Canadian dollars at current exchange rates ($1.00 U.S. = $1.154 Canadian). **Source:** Statistics Canada

Canada, says EAITC, has two advantages that could aid the specialty chemicals sector. First, raw material costs generally are low. And Canada has plenty of space for potential plant sites. This could entice European companies to invest in Canada and, under the trade agreement with the U.S., gain tariff-free access to the U.S. market.

The same holds true for advanced materials. With few exceptions, the Canadian plastics products industry is weak. Activity in composites, laminates, and ceramics is modest. In advanced materials, other countries have the technological edge. With very few Canadian companies positioned to exploit the advantages offered by a more unified EC, Canada's best bet lies in attracting European—and other foreign—investment in advanced industrial materials. Foreign investment already is in place in the Canadian pharmaceutical industry. But that doesn't mean the industry will be able to reap some of the advantages that are sure to come as the EC moves toward harmonized product standards and licensing procedures.

Most of the companies in the Canadian pharmaceutical industry are subsidiaries of U.S. and European multinationals. For the most part, they perform modest processing operations. The parent companies already are on the scene in Europe.

If top management assigns world-scale production of some products to the Canadian subsidiaries, Canada could benefit. However, most Canadian pharmaceutical branch plants are small. Many are old and labor-intensive. As a result, there are likely to be few production mandates from multinational headquarters.

The other part of the Canadian pharmaceutical industry—the generic drug manufacturers—could stand to benefit somewhat. Canadian companies have a lot of experience in generic drugs. As patents expire, this experience could help them take advantage of the European situation by increasing their exports to Europe or by attracting European investment to Canada.

However, even after the 1992 plan takes effect, European licensing procedures may remain too cumbersome for most Canadian generic drugmakers. Profit margins are low on European generic sales because of the overcapacity that already exists there. For the next several years, says EAITC, Canadian generic drugs will find better markets in other parts of the world. The EC's 1992 plan then promises only modest benefits for Canada's pharmaceutical industry. The possible exception is biotechnology. Canada has several new small but energetic biotechnology firms specializing particularly in vaccines, insulin, and diagnostic kits. And Canada's traditionally strong resource industries give the fledgling Canadian biotechnology companies a head start in applying their trade in those potentially huge markets.

Biotechnology, says EAITC, is a field in which Europe seems to lag. As a result, it expects Canadian biotechnology companies will be big gainers from the EC plan. Their biggest competitors will be U.S. and Japanese companies. But Canadian biotechnology companies are quite capable of exploiting market opportunities in the new Europe after 1992. □

say, £100 per mg, they would be no good for the pharmaceutical researcher. You must find a way of synthesizing [them]."

Dextra has pilot facilities with reactors capable of producing runs of 6 L. As Lawson and Hacking point out, for a pharmaceutical company, 1 g is quite a lot. The company's current projects range from milligram to kilogram scale.

"Other companies have wanted our knowledge rather than our synthesis. For example, they will contract with Dextra for the company's in-house expertise of food rheology or food chemistry, so the activity can be utilized properly, but the product itself can be palatable," says Lawson.

"The thing we hope will make the business grow will be new products, in addition to making specialized products for companies," he adds. "We watch the activities of other companies—they make lots of products, but their lines are unfocused. We're beginning to learn what companies are looking for: both the products they are asking for, and what they might be needing in the way of intermediates."

The two are convinced carbohydrate chemistry is a stepchild research area. "If you talk to companies about proteins, there is enormous interest throughout a company. But if you talk about carbohydrates, there are only little spatters of interest," says Hacking.

One branch of science seems to have outstripped another, they believe. A great deal of knowledge about carbohydrates in human tissue has been discovered by biochemists and immunologists who have worked out the functions of carbohydrates and how to mimic them. "If you could modify this carbohydrate with, say, this modified tail, it could enter the tissue; the tail sticking out could act as a target for a drug," says Lawson. The research imbalance, however, occurs because the analysis "has proceeded as far as it has, but there are not enough chemists trained in synthesizing carbohydrates."

Until that lack is addressed, at least, they see a bright future for Dextra, with its carbohydrates know-how.

Patricia Layman

Chlor-alkali industry focuses on transition

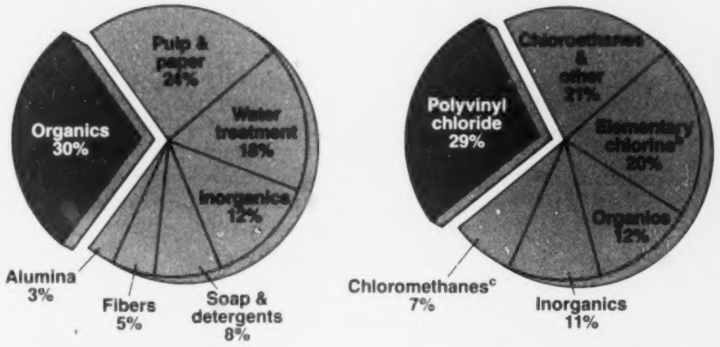
Pressures on end-use markets, imbalances in chlor-alkali demand, technological innovations, and social responsibility are forces the chlor-alkali industry is now facing. Late last month, at the 2nd World Chlor-Alkali Symposium, entitled "An Industry in Transition," about 600 industry members, customers, and representatives from government and environmental groups from more than 30 countries met in Washington, D.C., to examine the impact on business.

In the hierarchy of chemical production, chlor-alkali ranks near the bottom. As such, chlorine and sodium hydroxide (caustic soda) form the basis of numerous chemical processes. Chlorine, a coproduct in the electrochemical production of sodium hydroxide, is used in many plastics, solvents, chlorofluorocarbons, and other organic chemicals. Most major chemical companies are chlor-alkali producers or consumers, with the market adding up to a few billion dollars per year.

Key issues are those surrounding major chlorine end-use markets such as pulp and paper, water treatment, and polyvinyl chloride production. All such markets are facing environmental and regulatory pressures with an emphasis primarily on the by-products of chlorine use. These include the formation of chlorinated organics in water treatment and the formation and possible effects of trace amounts of dioxin in pulp and paper bleaching. The impact of plastic packaging, in this case PVC, in solid waste and incineration is raising concern. Other products such as chlorinated solvents and CFCs are targets for elimination, having been identified as environmental or health hazards.

Rather than being moved by traditional economic forces, the industry is facing increasingly aggressive attacks on its products, says J. Roger Hirl, president and chief operating officer of Occidental Chemical. With each of the major market segments that use chlorine in products or processes under pressure to restrict or eliminate its use, he calls the changes faced by the industry a result of "revolution rather than evolution." These pressures are expected to upset an already "precarious market imbalance" between the decreasing demand for chlorine and the increasing demand for caustic soda.

"Survival of the industry is directly linked to the survival of its key markets in what is becoming an increasingly hostile environment for chlorine-based products," says Hirl, requiring industry associations to become more adept at communicating chlorine health, safety, and environmental information. "[The in-



Caustic is used most in organic chemicals...

...and chlorine most in polyvinyl chloride

1989 U.S. consumption = 22.4 billion lb[a]

1989 U.S. consumption = 22.9 billion lb[a]

a Department of Commerce apparent consumption figures. b Used in disinfection and pulp and paper. c Used in manufacture of chlorofluorocarbons.

dustry] needs to understand and anticipate change in new and innovative ways or . . . be swept away with its consequences."

What must be anticipated are dramatic changes in traditional markets via the substitution of other products for chlorine. Although chlorine is the most frequently used disinfectant and is responsible for irradicating many diseases, in water treatment it has been cited in the formation of the suspected carcinogens, trihalomethanes or THMs. To comply with regulations on the release of THMs, most water treatment facilities will consider other options, says Richard Moser, vice president at American Water Works Service Co., Voorhees, N.J. However, replacements to chlorine have tradeoffs in cost, effectiveness, and byproducts that must be considered.

More stringent and prevalent final regulations, affecting virtually every water treatment facility, are expected to be promulgated by late 1991 or early 1992 with about three years allowed for compliance. Chlorine use may diminish greatly as water utilities discontinue its use, adds Moser.

The pulp and paper industry, while under pressure to reduce its use of chlorine, maintains a need for caustic. Pulp and paper uses about 15% of chlorine produced and about 23% of caustic soda, says Bruce Fleming, director of the chemical pulping and bleaching division of the Pulp & Paper Research Institute of Canada. The shifting balance is expected to affect overall caustic and chlorine prices. Chlorine's share of the world bleaching market will drop from 36% to 26% in the next five years, he predicts, while caustic use will remain essentially constant or even increase.

In North America, chlorine use by the pulp and paper industry is expected to drop precipitously in the next five to six years. Which replacements for chlorine will be used in the bleaching process will depend on government regulations and the quality of paper demanded by consumers. Alternative routes to adjusting the chlorine/caustic ratio in the pulp and paper industry might be found through reduction, replacement, or other sources of caustic soda, Fleming says.

PVC production is often used as a means to counteract the imbalance in caustic/chlorine demand. World PVC production is operating at about 90% capacity, or about 40 billion lb per year, divided equally among major regions of the world. Changes in basic economic conditions such as the price of oil, housing starts (60% of PVC produced is used in construction), and automobile sales will greatly affect the demand for PVC, says Ryoji Endo, managing director of Shin-Etsu Chemical Co., Toyko. In addition, concern over the role of PVC in packaging (about 15% of PVC production worldwide) and its impact on solid waste, is causing some downturn in that market segment.

With growth in PVC demand per capita correlating closely with that of GNP per capita, developing nations will be important factors in the expansion of PVC markets. Growth is expected to be slower in industrialized nations where the market is more mature. Considering all factors, Endo estimates overall growth for PVC at 3 to 5% per year.

Dealing with the imbalance due to stagnating or declining chlorine markets and growing caustic markets will be difficult, concludes Jean Christiaens, managing director of Solvay & Cie. in Brussels. Although chlorine use will not be phased out immediately by the pulp and paper industry, in 10 years it is expected to consume one third of what it did 10 years ago. The production of chlorinated solvents, with nearly half used as raw material for CFCs, will also fall considerably. PVC may be the only market that can sustain growth in chlorine demand.

In contrast, says Christiaens, caustic soda is seeing growth in approximately 70% of its market segments and a decline in only about 10%. As with PVC, correlation between gross national product per capita and caustic consumption per capita indicates room for growth. The traditional cyclic nature of the chloralkali industry may have disappeared, he notes, but suggests that shortages and high prices may be avoided in the long term when a new equilibrium between supply and demand develops.

Ann Thayer

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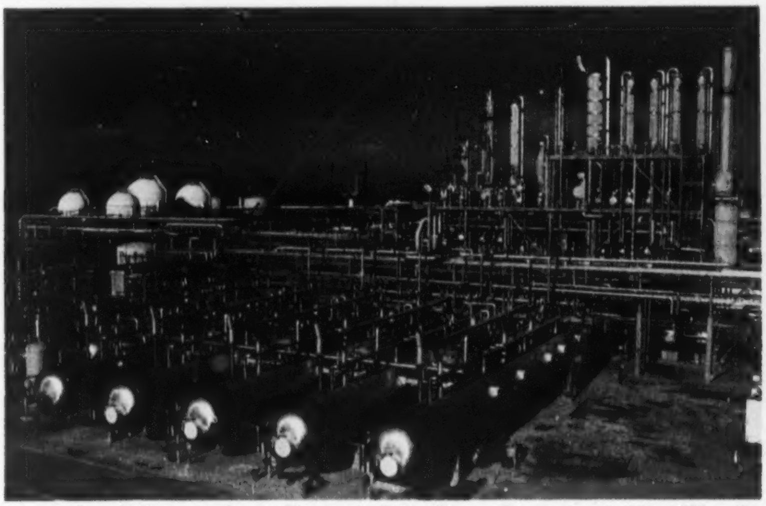
Demand for α-olefins continues to rise

Linear (or normal) α-olefins provide a bright growth prospect among large-volume basic chemicals and intermediates. Any economic downturn is expected to cut no more than two points off the annual growth rate of 5 to 7% for the reactive and diversely used α-olefins during the early part of the 1990s.

Relatively strong growth for these products is a carryover from the mid-1980s when their strong demand spurred all three U.S. producers to add capacity. The most recent capacity addition was at Chevron Chemical, which late last month started up a 250 million lb-per-year unit at its Cedar Bayou, Tex., plant, and celebrated the silver anniversary of the startup of the first commercial-scale unit to make α-olefins at that location.

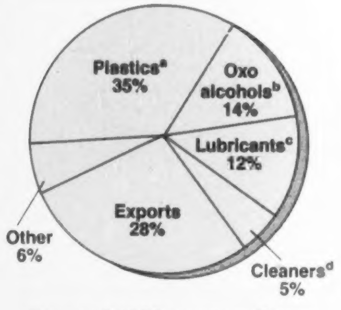
That expansion brings Chevron Chemical's α-olefin nameplate capacity to 500 million lb per year. Company officials at the dedication ceremonies, however, admitted the two units were currently being operated in excess of nameplate capacity. Additional capacity is expected through process improvements.

Also completed during Chevron Chemical's expansion project at Cedar Bayou are additional laboratory facilities, extension of process and quality control systems, and faster and improved loading systems. Dedicated storage capacity has been increased 110,000 barrels and is blanketed to minimize contamination.



Annual α-olefins capacity at Chevron's Cedar Bayou, Tex., plant is 500 million lb

Linear α-olefins go to a variety of markets



Forecast 1990 consumption = 1.6 billion lb

a Comonomers and polybutene. b Mostly plasticizers. c Additives and synthetic lubricants. d Includes surfactants and germicides. **Source:** C&EN estimates

Capacity expansions for α-olefins at Ethyl and Shell Chemical also have been completed recently. Current U.S. nameplate capacity totals more than 2.5 billion lb, and about 300 million lb of 1-butene made as a coproduct with other C_4 hydrocarbons. Capacity expansions are also under way elsewhere such as a new unit for Ethyl in Belgium.

Long-chain olefins, with the unsaturation between carbon atoms other than in the alpha position, also are sold commercially. However, the volumes of these internal olefins are small compared with α-olefins, the global consumption of which exceeds 2 billion lb per year.

Despite production of α-olefins in Western Europe and Japan, exports account for more than a quarter of U.S. output. Most of these go to industrialized countries in Europe as well as to Canada, Mexico, Japan, Taiwan, and Venezuela. Besides the olefins, numerous derivatives also are exported.

The largest use of α-olefins is as a comonomer in making various types of linear low-density and high-density polyethylenes. The majority of these olefins are 1-butene, 1-hexene, and 1-octene. Minor amounts of branched olefins may be used in some polyethylenes. A secondary plastics use is in polybutene. Strong growth in polyethylene foreshadows that the use of the comonomer will grow at 6 to 7% annually.

After exports (the second largest market for these olefins), the third largest use is in making a wide variety of long-chain alcohols by the oxo process. Most of these alcohols, by reaction with phthalic anhydride, are made into plasticizers for polyvinyl chloride. But these plasticizers have competition from dioctyl phthalate (containing a branched-chain olefin) on a cost and performance basis. Some of the oxo alcohols go into surfactants, as do other α-olefins that are sulfonated.

Various synthetic lubricants are made of small polymers of α-olefins. These products and various esters made of synthetic fatty acids from these olefins are used as lubricants and as additives to improve conventional petroleum-based lubricants. They account for more than 10% of consumption.

About 10% of α-olefins go into a variety of intermediates and end products. Examples include various fatty amines and derivatives for detergents, alkenylsuccinic anhydrides for paper sizing or leather treating, long-chain mercaptans as chemical intermediates, and various epoxides. Some of these specialty chemicals have high growth rates from small-volume bases, but their total demand growth will be about average for all α-olefins.

Bruce Greek

Stepped Up Biomedical Spending on Training, Research Labs Urged

In spite of current funding squeeze, Institute of Medicine panel calls for channeling more money into training, construction, and equipment

Pamela S. Zurer, C&EN Washington

Sponsors of biomedical research must put more funds into training young scientists and improving research facilities, an Institute of Medicine committee has concluded—even if that means less money for research grants.

Scientists already in despair over the recent dramatic decline in new research grants from the National Institutes of Health, the single largest source of support for biomedical research, may find that message hard to swallow (C&EN, July 16, page 20). But IOM panel chairman Floyd E. Bloom, head of the neuropharmacology department of the Research Institute of Scripps Clinic in La Jolla, Calif., says the current funding squeeze does not justify shortsightedness.

"Unless we as scientists state how we would spend our money for the good of the system over the long run, we can't expect that sponsors would be willing to go along with requests for more money just because things are tight at the moment," Bloom told a recent symposium at the National Academy of Sciences in Washington, D.C. The seminar was held to present the report, "Funding Health Sciences Research: A Strategy to Restore Balance," which IOM's committee on policies for allocating health sciences research funds spent two years putting together.

The panel's goal was to analyze the balance in funding for research projects, training, facilities, and equipment and to recommend any necessary corrections. The committee's task was made tougher by IOM president Samuel O. Thier's stipulation that they could not simply ask for more money.

Training should have highest priority

The Institute of Medicine's committee on policies for allocating health sciences research funds concludes:

- The development of individual career scientists, who contribute through both their own research efforts and by training future scientists, is the most critical and longest term investment in the research system.
- Capital investment in facilities has a slightly shorter expected usefulness to the research enterprise.
- Individual research projects and equipment are generally the shortest and most variable investments over time.

"It was clear to everyone on our committee that we need more money," Bloom says. "But the goal of the study was to analyze the ways we spend money to see whether we can maximize it so we can guarantee to our sponsors that when more monies are available they will be put to the best use."

Many on the panel were surprised to find that—despite the pervasive gloomy view that biomedical research funding is declining—total U.S. support has been increasing progressively even when inflation is taken into account. In the past few years, however, fewer and fewer grant applications have been successfully funded at NIH because of a combination of factors. These include increasing numbers of grant applications, higher research project costs, and an increase in the average grant length.

Meanwhile, a larger and larger share of the available funds has been going to support research projects at the expense of training, construction, and equipment—a source of great concern to the committee.

"The system has largely been feeding upon itself in order to maintain the emphasis on . . . research projects," Bloom says. "As funds have been dedicated toward R01 [NIH's traditional investigator-initiated research grant] and program project grants, the result has been a progressive diminution in the case of training and an almost total elimination in the case of research facilities construction."

Specifically, although the dollar amounts for NIH training programs have held roughly steady over the past two decades, they have now slipped to about 4% of NIH's extramural budget after accounting for about 18% in 1971. And federal funds for research facilities have been negligible over the past decade except for a limited amount for AIDS.

"In the course of the 1980s, very severe pressures occurred despite rising overall NIH budgets as a result of the explosion of attractive targets of opportunities for current research dollars," says Henry J. Aaron, a panel member who is an economist with the Brookings Institution in Washington, D.C.

As a result, NIH and other organizations "responded in a way that is perfectly natural and rational for a short-term period of stress," Aaron says. "They shifted the emphasis of expenditures from categories that produce relatively long-term payoffs—specifically buildings and equipment and training—to fund those activities that produce immediate payoffs—namely support of current research."

Committee member P. Dennis Smith, professor of biological sciences at Wayne State University in Detroit, explains how the panel's analysis of those trends and of the scientific personnel pipeline led them to worry where the researchers of tomorrow will come from.

"By 1995 we will have a confluence of two unfortunate outcomes," Smith says. The number of people coming into the pipeline is decreasing because of a decline in the number of high school graduates. At the same time, by 1995 there will be a large attrition from retiring university professors.

The committee decided the distribution of funds across the three broad categories of current research activities, physical capital, and human capital is currently out of balance. It recommends a shift of resources—even within the severe current funding restraints.

"The current pattern is not sustainable," Aaron says. "A shift in emphasis toward an investment in human and physical capital is necessary for the long-term health of biomedical research. Unless such a shift occurs we will not adequately replenish the stock of trained personnel to carry out research and we will not be giving them adequate research equipment and structures with which to carry out research."

The committee makes specific recommendations on how NIH's budget might be reallocated over the next decade under four different budget scenarios—no growth beyond inflation, 2% real annual growth, 4% real annual growth, and a growth rate of greater than 4% a year.

"We felt we must do something to begin to gradually rectify what has occurred over the past 15 years," Bloom says, "even though we realize the growing problem in funding the number of very valuable research proposals that exist."

Under the no-real-growth scenario, the committee suggests shifting about $12 million a year of NIH's extramural budget into training programs until that segment reaches about 7% of the total budget in 2000. For comparison, about 5% of NIH's $5.6 billion fiscal 1990 budget is set aside for training.

"That would begin to increase the research talent pool at about 400 people a year—still far short of the projected need," Bloom says. "This is an absolute requirement even under the current tight funding situation."

Similarly, the construction segment of the NIH budget would grow from roughly 2% in 1990 to about 5% in 2000. As a result of these reallocations, both the absolute dollars and the percentage available for research grants would decrease slightly.

Under the more optimistic scenarios, training and facilities funds would grow faster than funds for research projects, which would grow modestly.

The panel also suggests several pilot projects aimed at easing the pain of researchers who fail to win grant money. The most controversial proposal involves partially funding grants on a sliding scale.

Under NIH's current grant review system, proposals are awarded a numerical score based on peer review. Monies generally are distributed on an all-or-nothing basis, with grant proposals whose scores fall above the "payline" being funded and the others not.

The sliding-scale experiment would protect proposals that fall just below the payline. Grant applications in the top 10% would get full funding. Those in the next 10% would receive a lower level of funding and the next 10% still less. The scope of the partially funded proposals would be reduced correspondingly, with the NIH study sections (peer-review groups) recommending which parts of the project to focus on.

"We're trying to extend the resources to a greater number of people," Bloom says, noting that the experiment would result in about 400 more grants being funded this year. The committee also recommends that research institutions be allowed to amortize buildings and equipment more rapidly to reflect that scientific facilities often become obsolete before their physical life has expired. The panel shied away, however, from a full examination of the thorny question of indirect cost calculations, other than to say the whole issue deserves a close look.

The panel also cites a need for better coordination of federal priorities for biomedical research. It proposes that the White House Office of Science & Technology Policy create a health sciences subcommittee to the Federal Coordinating Council for Science, Engineering & Technology. And it suggests formation of a roundtable to promote communication between research institutions, industry, government, and private foundations concerned with biomedical research.

Individual scientists must also work to make sure the system is in balance, the committee says. "Certainly if the scientific community does not come up with its own creative solutions, it's quite clear that Congress is going to impose some solutions on us," Bloom says. □

Plan would cut grants to add training and building funds

	1988		1989		1990		1995		2000	
	$ millions	%^{a}	$ millions	%^{a}	$ millions	%^{a}	$ millions	%^{a}	$ millions	%^{a}
Research project grants	$3765	69%	$3828	69%	$3822	68%	$3724	66%	$3640	65%
Research centers	963	18	987	18	998	18	1026	18	1054	18
Contracts	497	9	507	9	509	9	509	9	509	9
Training	239	4	255	4	267	5	323	6	379	7
Construction	0	0	7	1	14	2	28	5	28	5
TOTAL^b	**$5463**	**100%**	**$5583**	**100%**	**$5611**	**100%**	**$5611**	**100%**	**$5611**	**100%**

Note: Plan assumes no growth in NIH budget. Totals may not add due to rounding. a Percentage of NIH extramural budget. b Total NIH extramural budget. **Source:** Institute of Medicine

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OCTOBER 15, 1990

News of the Week

- **NASA gets badly needed boost as space shuttle *Discovery* launches *Ulysses* spacecraft on mission to explore Sun's polar regions.** **Page 6**
- **Congress continues to work on budget, with impact on R&D still unclear.** **Page 7**
- **Foreign ownership of U.S. chemicals and allied products firms up almost 36% in 1989.** **Page 7**
- **Two U.S. physicians awarded Nobel Prize in Physiology or Medicine for discoveries related to human organ and cell transplants.** **Page 7**
- **NIH opens full-scale investigation into circumstances surrounding AIDS researchers' development of blood test for virus.** **Page 8**
- **Government-approved sales of electronics-related Hercules and Carbide chemical units to the Japanese draw fire during Senate hearing.** **Page 8**

Business

Polystyrene likely to experience a downturn in 1990 production as styrene cost rises and demand slumps. **Page 15**

French chemicals producer Rhône-Poulenc opens a $14 million pharmaceutical research center in the U.K. **Page 17**

Government

Little change in House or Senate rosters is expected as a result of the November elections. **Page 21**

EPA called on to tackle pollution problems that would offer greatest reduction in risk to health and environment. **Page 24**

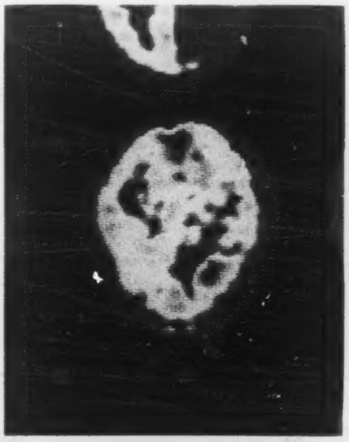
Education

NSF funds precollege science education reform program aimed at introducing dramatic changes in way science is taught. **Page 27**

Books

Why bright college students lose interest in pursuing science majors is explored in new book; book of poetry by Roald Hoffmann brings together worlds of science and art. **Page 69**

Cover: Colorized magnetic resonance image of the human brain; transaxial slice shows eyes and part of nose. Photo courtesy of General Electric Corporate Research & Development



Product Report

An ever-growing understanding of the molecular biology of the brain is helping chemists in designing the next generation of psychoactive drugs, which likely will be safer and more effective for treating mental illnesses. **Page 33**

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Chemical & Engineering News
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LETTERS

Alternative fuels

The public is gradually being lulled into the belief that gasoline in automobiles can be replaced by an alternative fuel that will radically reduce pollution.

If an alternative fuel is defined as one that will give reasonable performance and economy compared with gasoline, and exists in comparable supply, there isn't any. There have been many excellent articles dealing with alternative fuels, but the authors tend to emphasize the pollution aspects and ignore economics and logistics. One seldom sees any numbers in such articles. The same alternative fuels have been here for 40 years; how many automobiles do you see running on alternative fuel?

David A. Spitz
Columbus, Ohio

Funding for science

I was disturbed after reading the interview with our national science adviser, D. Allan Bromley (C&EN, July 2, page 12). Bromley talks about scientific extravaganzas on page 14; a few pages before, the crisis in biomedical research funding is discussed. What's going on here?

The space station, I understand, will cost on the order of $40 billion to build and another $80 billion to operate, while the Super Collider bill has grown to $8 billion and the human genome project will cost $3 billion. That's not counting the ambitious Moon-Mars project or Mission to Planet Earth.

An underlying assumption is that all these projects are merited. Where is the rigorous review? Is this how we want to allocate our resources now? Could the money be better used for less showy, less ambitious projects? Where is our list of priorities? Do we really want to abandon older projects supporting biomedical research—such as those discussed in the News of the Week article on page 4?

Big science is crowding out the many small federal grants that sustain this country's researchers. Too many big science projects were approved uncritically without concern for their impact on smaller projects that are the seed corn of technical advance.

Bromley was quoted as saying, "A significant amount of excellent science is now not being funded." My question to Bromley is, wouldn't it be more in the national interest to fund Nobel Laureates like Harold Varmus than all the space extravaganzas? I'd like to see you advocate for individual investigators working to make incremental advances in science with the support of federal funding.

Let's not have American policymakers modeling the pharaohs who wasted their nation's resources on showy extravaganzas. Let's build for the future.

Louise Vivona
Research Investigator, Bristol-Myers Squibb Co., Bound Brook, N.J.

After reading the July 2 issue of C&EN, I have found the need to comment on the (seemingly) relentless campaign waged by ACS for increased federal R&D funding, increases in the National Science Foundation budget, and other governmental "assistance" to the scientific community. Any funding by the government must come from the pockets of taxpayers, not some invisible philanthropist. The burden placed upon the taxpayer is far too great at present, and every effort must be made by societies such as ACS to help reduce the present burden rather than increase it for that society's perceived benefit.

Certainly, money is always needed in education, research, and development, as well as thousands of other worthy causes. Does anyone actually believe that an increase in federal funding will serve to enhance the future of science? To expect an extremely partial government—pressured by lobby groups from all sides—to be impartial and purely subjective in the disbursement of funds is too much to ask. Our politicians are too human and subject to the temptations of power and the pressures of their voting public to make these decisions without bias.

So remove the temptation by removing the countless tax-funded programs and allowing industry and private citizens and groups to support their favorite causes freely, without tax consequence. Our country, socially as well as economically, runs best when allowed to run freely, without interference.

Michael J. Verive
Addison, Ill.

Science education

A matter has come to my attention that I wish to pass on to you. This relates to that aspect of your special report on science education (C&EN, June 11, page 27) where there is depicted those in the science personnel pipeline as their educational attainment increases (also shown in years). A plot of the number of people

Polystyrene Heads for Down Year In Face of Market Pressures

Polystyrene output to drop as oil prices push monomer costs up and economic and environmental concerns slow growth in demand

Bruce F. Greek, C&EN Houston

Polystyrene has some problems. Beset by rising monomer costs and low demand growth, it can only be said to be experiencing a slump. Styrene and benzene prices are rising, as crude oil prices shoot up. Demand for polystyrene is slipping for a number of reasons including environmentalists' opposition to single-use packaging, a weakening of the economy, and a falling off of exports as new capacity starts up in other parts of the world.

Several forecasts conclude that 1990 production of polystyrene will decline about 1%, from 5.13 billion lb in 1989 to about 5.05 billion lb this year. The forecasts are contingent upon oil prices remaining doubled as long as the Middle East situation continues and the possibility of a recession exists. If output slips this year, it will make the second straight year of production declines.

A recession next year would, of course, have an impact on production, but no repeat of the 20% decline during the 1982 recession is expected. If crude oil prices fall back to about $20 per barrel, 1991 inventory building could tip production up over the 1990 output.

A small decline in polystyrene output last year and one likely this year will follow a huge growth for the mature product between 1985 and 1988, says William E. Pearson, who heads Partridge Plastics Associates in Midland, Mich. Polystyrene output increased more than 25%, or more than 1.1 billion lb, in three years, which is far above the 2 to 4% growth expected for this plastic. But such growth is not sustainable, and the 1989 output decline of 1.6% was generally anticipated.

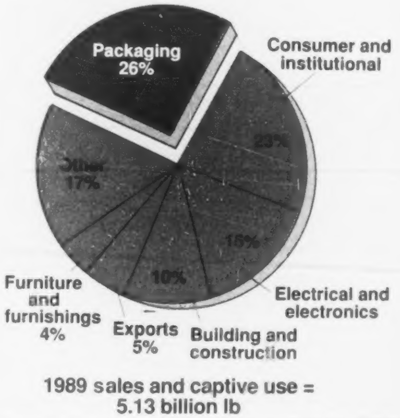
During the first half of this year, polystyrene output declined more than sales and captive use, according to data compiled by Ernst & Young for the Society for the Plastics Industry Committee on Resin Statistics (CRS). This inventory drawdown, which may have extended into the third quarter, likely will cause a rebound in 1991 production. Inventory building could be further spurred by more relatively low-cost styrene becoming available as two large plants go into production.

Problems with styrene availability are partly the cause of an inventory drawdown. In July, an explosion and fire at Arco Chemical's plant near Channelview, Tex., knocked out about 1.4 billion lb of styrene capacity (C&EN, July 16, page 4). Prior to that incident, various Gulf Coast producers of styrene had experienced operating problems stemming from damage caused by an unusually harsh freeze at the end of last year. During the first half of 1990, styrene production was down more than 4% from the first half of 1989, according to estimates of the U.S. International Trade Commission.

Despite lost production, no serious shortages of styrene occurred, says Steve D. Knight who specializes in studies on styrene and its derivatives at Chemical Marketing Associates in Houston. Additional imports and reduced exports of styrene helped to provide supplies. Some small capacity expansions coming on stream during the second quarter also helped meet demand.

Substantial increases in styrene capacity are coming soon, Knight says. He cites a restart of the Arco Chemical unit and the completion of a Chevron Chemical expansion that combined are expected to have 2.3 billion lb of annual capacity available at the beginning of 1991. Other plant expansions are due later, both in the U.S. and worldwide. Between 1990 and 1997, Knight puts the total of these expansions at 14.3 billion lb, or a 44% increase over the base global capacity of more than 32 billion lb in 1990. These capacity expansions will average 5.7% annually, and are above the expected growth in major uses such as polystyrene. They will make the world styrene market very competitive.

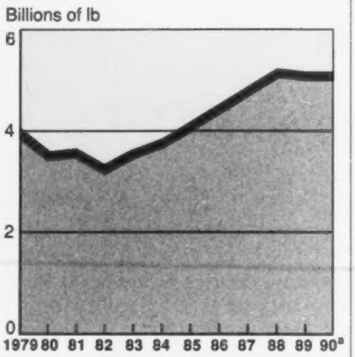
Packaging takes largest share of U.S. polystyrene use



1989 sales and captive use = 5.13 billion lb

Source: SPI Committee on Resin Statistics Annual Major Market Survey

U.S. polystyrene output goes on hold



a Forecast. **Sources:** SPI Committee on Resin Statistics, compiled by Ernst & Young, C&EN estimates

The price of styrene, especially on the spot markets, seesawed during the first half of this year, further affecting polystyrene output and adding to the inventory drawdown. Current prices are rising because of an increase in benzene prices that has been triggered by escalating crude oil prices. Styrene prices have made polystyrene more expensive, especially relative to other thermal plastics that have somewhat similar properties.

In some uses, polystyrene was priced out of its low-end markets, says Pearson. The interpolymer competition came mostly from polypropylene, with only very minor amounts from high-density polyethylene. The shift, however, was so small in most of these uses that details are difficult to determine from available statistics.

Besides interpolymer competition, polystyrene also has been hit by competition from other materials, particularly paper, according to William C. Kuhlke, who directs studies on plastics as a vice president of DeWitt & Co., Houston. Cost and the more favorable image of being degradable or recyclable have boosted paper into more competition with plastics. However, the effect of paper and other nonplastic materials upon the demand for polystyrene also will be difficult to find in statistics.

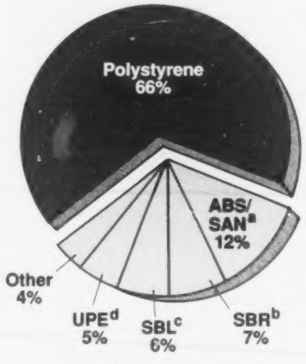
Recycling is greatly helping polystyrene as well as other plastics such as polyethylene and thermal plastic polyester, points out Kuhlke. At least four recycling plants designed to handle polystyrene are being built. These should help improve polystyrene's public image, he adds.

As recycling grows later this year and accelerates next year, few concerns likely will develop over the effect on new polystyrene. Kuhlke forecasts that a large part of recycled polystyrene as well as other plastics will be consumed in fabricated products not now made of plastics. Recycled polystyrene's impact on production of new material will be so small that it probably will be lost in statistical error.

Considerations other than polystyrene cost influence decisions about whether another polymer will be substituted in many fabrication processes, says Pearson. Polystyrene has two major advantages. It has easier processibility than any other large-volume thermal plastic, and its maturity means that many plastics fabricators have lengthy experience in forming polystyrene. These considerations often tip the scale toward continued use of polystyrene, even if its cost becomes significantly more than other acceptable plastics for a product.

The cost and processibility factors help polystyrene retain its demand despite the high negative image gained from its use in many kinds of packaging—an image mainly developed from consumers' discarding containers in public areas and from the long life, and therefore long visibility, of such containers.

Polystyrene dominates global styrene use



1990 global styrene consumption = 30 billion lb

a Acrylonite-butadiene-styrene/styrene-acrylonitrile. b Styrene-butadiene rubber. c Styrene-butadiene latex. d Unsaturated polyester. **Source:** Chemical Marketing Associates

Only two of the major end-use categories compiled by Ernst & Young for CRS for polystyrene have shown a decline through July. Exports are down 14% from the comparable period in 1989, and consumer and institutional products are down 29%. The large decline in consumer and institutional products use could be partly a statistical aberration, Pearson says, because of misclassification. Better analysis of uses could cause reclassification of some of the "all other" category, rendering a better report in this category.

Consumer and institutional products made from polystyrene number in the thousands. For example, some of these products used in hospitals have been replaced by reuseable items. Toys, housewares, and other products made of polystyrene apparently are in less demand as consumers change their interests and lifestyles. The sizable downturn in polystyrene consumption in this category has abated and is expected to recover. Because of increased polystyrene capacity outside the U.S., particularly in the Far East, exports continue to decline as expected (but not so fast as earlier in the year). Styrene capacity in the Far East also is rising rapidly, lowering the monomer cost as well. Polystyrene price increases, which helped interpolymer competition outside the U.S., hastened the decline in exports earlier in the year.

Polystyrene consumption, especially in the U.S., will increase only modestly in the long term, as no important new uses are expected soon. Following the trend of earlier this year, low demand growth will continue to squeeze the margins from selling this plastic, made with high-cost monomer. Relief from any pressure on styrene costs resulting from increased capacity next year remains doubtful unless crude oil prices fall. Rebuilding inventories at various steps between polymer manufacture and consumer product sales could become the major reason for any recovery in production next year. ☐

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Hong Kong's chemical community feels impact of 1997 reintegration with China Page 21

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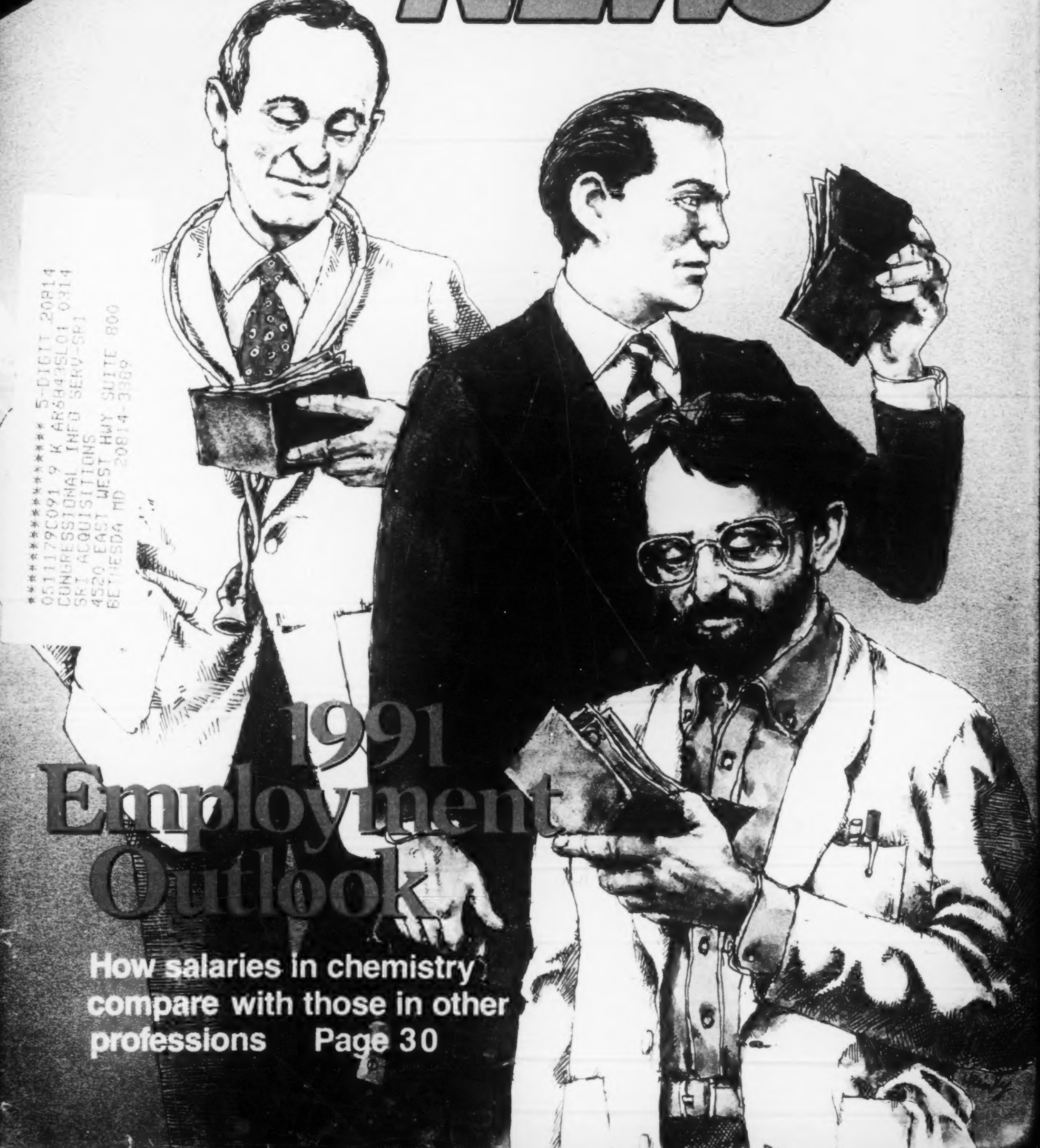

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1991 Employment Outlook

How salaries in chemistry compare with those in other professions Page 30

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CHEMICAL & ENGINEERING NEWS

OCTOBER 22, 1990

News of the Week

- **Nobel Prizes in Chemistry and Physics announced, with chemistry award going to Harvard's Elias J. Corey.** **Page 4**
- **Third-quarter chemical earnings reported so far indicate that earnings may be down at firms heavily tied to downstream petrochemical products, but up at others.** **Page 5**
- **White House appoints 39-year-old physician/lawyer David A. Kessler as new FDA Commissioner.** **Page 5**
- **Japanese researchers demonstrate a novel, three-state chemical method based on an azobenzene derivative that may prove useful for information storage.** **Page 6**

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Business

Chemical industry is shifting to managed health care benefits in effort to contain escalating health care costs; European chemical industry tackles environmental issues and challenges; Du Pont harvests specialty chemicals from waste streams, saves waste disposal costs and turns a profit. **Page 9**

Government

EPA's 1988 Toxic Release Inventory shows reduced industrial pollution, with biggest decreases found in chemical industry; World Bank issues report of its environmental activities, as it grapples with the ecological effects of its programs. **Page 15**

Science/Technology

Hong Kong must cope with continuing brain drain as colony prepares to recede to China in 1997; devices that treat diseases by selectively altering the body's immune system developed at Applied Immune Sciences; researchers encapsulate living cells in a polyphosphazene in aqueous solution at room temperature; dramatic new photos taken with Hubble Space Telescope and first photos taken with Roentgen Satellite released by NASA. **Page 21**

Awards

ACS award winners: Abeles, Alexander, Alkire, Blout, Casey, Chambers, Collman, Cooks, Debnam, DeStevens. **Page 49**

Employment Outlook

C&EN's annual look at the job market compares salaries earned by chemists and chemical engineers with those of other professionals. **Page 30**

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LETTERS

Iodine-doped polymers

In the debate on the conduction mode in iodine-doped nonconjugated polymers (C&EN, May 7, page 53; June 4, page 2), all participants have overlooked one piece of data that, to us, seems highly relevant: In 1980, I. Rubinstein and E. Gileadi (*J. Electroanal. Chem.*, **108**, 191) proposed a "super-ionic" relay conduction mode for the system iodine doped with 1M potassium iodide. The maximum conductivity was determined to be 10^{-2} siemens per cm, the same order of magnitude as was determined for "conducting rubber" and all other iodine/polydiene complexes. With iodonium complexes (Bruce Hudson), iodinium complexes (Gary Wnek), iodine ions in systems with up to 60 to 70% (Mrinal K. Thakur), iodine can readily do the job.

A. H. Alberts
E. W. Meyer
Eindhoven Technical University
The Netherlands

Opera fan of Risë Stevens

As an opera lover and fan of the Met, I must take exception to John H. Nair's deprecation of Risë Stevens, calling her "a minor opera singer" (C&EN, Sept. 24, page 3). Her definitive portrayal of "Carmen" alone earned her international acclaim as one of the great operatic artists of her time.

Hans Wagner
Wilmington, Del.

Kekulé's dreams

In Royston M. Roberts' review of Alexander Kohn's book, "Fortune or Failure: Missed Opportunities and Chance Discoveries in Science" (C&EN, July 23, page 61), Roberts disagreed with Kohn, who considered Kekulé's claim to have discovered the structure of benzene in a dream a "myth which has recently been laid to rest." Roberts backs up his difference of opinion by calling attention to "considerable current interest, as indicated by recent controversial publications and a [Kekulé] symposium presented by the Division of History of Chemistry at the Boston national meeting of the American Chemical Society last April."

I was the organizer of the Boston two-day Kekulé symposium. Indeed there was a lot of interest. We had speakers from the U.S., Belgium, Germany, the Soviet Union, and the U.K. Besides participation by chemists, there were presentations by historians of chemistry and of science, psychology, and psychiatry. When the papers are published in 1991 in book form by Springer-Verlag, I believe that your readers will side with Kohn's opinion. I believe that the chapter by the psychiatrist Albert Rothenberg, the director of research at Austen Riggs Center Inc., in Stockbridge, Mass., will be the last word that will support the revisionistic appraisals of the other investigators who considered Kekulé's dreams to be fictional.

John H. Wotiz
Professor Emeritus
Southern Illinois University

Royston M. Roberts referred to the American Chemical Society symposium in Boston regarding August Kekulé's discovery of the structure of benzene. At that symposium, I presented three commissioned expert English translations of Kekulé's original German description of the mental events leading to the discovery. All of these translators independently indicated that the word Kekulé used to describe his mental state, "Halbschlaf," did not refer to actual sleeping, the only mental state in which dreaming can occur. Also, other aspects of his own description contain clear references to his having visualized mental images in a waking state of mind.

Much of the misconception about the matter of dreaming has arisen from a faulty English translation done in 1898 by Francis R. Japp. In context, Kekulé's use of the verb to dream (träumen) seems clearly to have been intended as a figurative term in a manner similar to Martin Luther King's famous phrase, "I have a dream," meaning imagining or being inspired. Actual dreaming, it should be emphasized, is not the same psychological state as imaginative or in-

Correction

- Oct. 1, page 7: The U.S. Patent & Trademark Office has said that an interference between claims to single-chain antigen-binding proteins in Creative BioMolecules' pending patent application and a patent held by Genex Corp., Gaithersburg, Md., has not been declared. In early September, Creative BioMolecules filed a request for an interference, which, according to the company, is still pending.

EPA's Emissions Inventory Shows Some Pollution Reduction

Tally of 1988 reports from industry reveals 11% drop in emissions, chemical transfers from 1987 with chemical firms making greatest strides

David J. Hanson, C&EN Washington

An Environmental Protection Agency analysis of the 1988 Toxic Release Inventory finds that U.S. industry is beginning to reduce emissions of toxic chemicals, but it still has a long way to go. Chemical companies, which release the greatest amounts of toxic chemicals, are also the facilities making the greatest reductions in emissions and waste reduction.

This second national report on the toxic inventory says that companies' emissions and chemical transfers are down 11% from totals reported the previous year. These reductions come from pollution prevention and a lesser amount of hazardous chemicals being sent to municipal water treatment works or shipped to other treatment/disposal facilities.

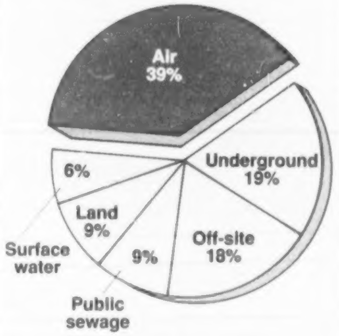
The raw numbers were made available last April. U.S. companies reported emitting 360 million lb of toxic chemicals into rivers, lakes, and other bodies of water; 2.43 billion lb into the air; 560 million lb to landfills; and 1.22 billion lb into underground wells.

According to EPA, Texas and Louisiana accounted for 24% of all releases and transfers of chemicals on the Toxic Release Inventory. Just three chemical companies—Du Pont, Monsanto, and American Cyanamid—reported releasing 710 million lb of chemicals into the environment, 15% of the national total. The chemical industry also had the greatest amount of pollution reduction, 11.6 million lb, of any single industry group.

The toxic inventory is part of the Emergency Planning & Community Right-To-Know Act, passed in 1986 as part of the Superfund reauthorization. The law requires all manufacturing companies that use certain levels of chemicals to detail how much they emit into the environment. The list of toxic chemicals Congress wrote into the law is a combination of lists developed by the states of Maryland and New Jersey for their own purposes.

The original list covered more than 320 chemicals and chemical categories. About 120 of those substances are considered carcinogens for the purpose of reporting. One chemical, Freon 113, is on the list solely because of its purported danger to Earth's stratospheric ozone. Some of the original listed chemicals, such as sodium sulfate, turned out to be not very toxic and were taken off the list, while others have been added.

Air emissions are largest source of toxics



1988 total releases = 6.24 billion lb[a]

[a] Emissions of substances on Toxic Release Inventory. **Source:** Environmental Protection Agency

In 1989 EPA received more than 70,000 forms from 19,762 facilities reporting their 1988 emissions. This is about 100 more facilities than reported 1987 emissions and an increase of about 4400 forms. Much of the difference stems from a lower reporting threshold used for 1988 reporting. In 1987 facilities had to manufacture at least 75,000 lb of a chemical before reporting was required. For 1988 the threshold was reduced to 50,000 lb, and next year it will be 25,000 lb. Despite the large number of facilities that did file forms, EPA estimates there are nearly 10,000 more companies that should be filing but are not.

Although these chemicals are labeled toxic for the purpose of the inventory, EPA cautions several times in its report that the releases reported are not an indicator of any human health or environmental problems. According to EPA's David Sarokin, project manager for the Toxic Release Inventory report, this is the first time EPA has made any comments about possible health effects. "The question of what is and what is not a toxic chemical is very difficult to answer. What we did in the report was to present the status quo—if a chemical was labeled as highly toxic on the inventory, we just carried that on over into the report."

Following the release of the preliminary data, a number of activist environmental groups released compilations of numbers designed to inform local residents of the large numbers of "toxics" in their communities. The National Wildlife Federation, for example, published a document called "Phantom Reductions" decrying the fact that most of the reported reductions from large companies were the result of changes in reporting requirements and new estimation methods.

EPA continually revises its toxics inventory

The Toxic Release Inventory is not a static list of chemicals. The Environmental Protection Agency has the ability and obligation to revise the list to keep it accurate and up to date. Since the law requiring compilation of the inventory was enacted in 1986, a number of chemicals have been removed and added.

Between the 1987 and 1988 reporting dates, EPA deleted four chemicals from the list. Three of the chemicals—C.I. Acid Blue No. 9 (diammonium salt), C.I. Acid Blue No. 9 (disodium salt), and melamine crystal—were of minor importance. But deletion of the other one—sodium sulfate—had a major impact, because sodium sulfate by itself, accounted for 55% of the total releases and transfers reported in 1987. Data on it were dropped from the 1987–88 comparisons.

Deleted from the inventory data for 1989 will be sodium hydroxide and nonfibrous forms of aluminum hydroxide. These also have large-volume releases and will cut the total release amount of chemical "contaminants" considerably.

But chemicals are being added, too. For the 1990 reporting period, EPA will add nine compounds: allyl alcohol; creosote; 2,3-dichloropropene; *m*-, *o*-, and *p*-dinitrobenzene; dinitrotoluene; isosafrole; and toluene diisocyanate. Nine chemicals are proposed for deletion next year as well. The largest volume of these are phthalic anhydride, terephthalic acid, and butylbenzyl phthalate. These contribute about 16 million lb to the annual inventory.

Sarokin admits that this is true, but says it is still too early to be extrapolating any kinds of trends from the data. When companies compiled their first reports for 1987, many, if not most, were confused about just what had to be reported and were unsure of how to estimate their emissions. EPA reported that almost all the early forms submitted were done incorrectly and had to be amended. Adjustments in the second year were expected, Sarokin says, although it is unusual that almost all of them were down. Overall, two thirds of the reductions in emissions are attributed to changes in reporting and revised estimates and one third to actual pollution abatement.

The 3838 chemical facilities (as defined by the standard industrial classification code 28) that filed toxic release forms for 1988 were only 19% of all facilities emitting toxic chemicals, but they accounted for 47% of total chemical releases and transfers. Running a distant second in terms of toxic releases, with 14% of the total, were primary metals (SIC 33). The chemical industry reported an average of four chemicals released per facility and had the greatest number of chemicals reported by one plant, 86 separate chemicals, by Dow Chemical's plant in Freeport, Tex. The petroleum refining industry (SIC 29) averaged the most forms per facility with eight.

Of the 120 chemicals on the toxic list labeled carcinogens, the chemical industry released or transferred three times as many pounds of the top 25 listed carcinogens as any other industry, although carcinogenic releases accounted for only 6% of the chemical industry total. Some of these carcinogenic compounds, such as hexachlorobenzene, are used and released solely by chemical plants. Chemical facilities also account for over 75% of the releases of many other carcinogenic compounds such as 1,3-butadiene and acetonitrile.

The toxic release inventory does not cover all sources of the listed chemicals, because, as EPA points out, many emitters either fall below the reporting thresholds, have less than 10 employees, or are in nonmanufacturing industries. The question remains, of course, how much of any chemical's releases are caught by the Toxic Release Inventory?

EPA says it depends. Releases of some chemicals, such as acrylonitrile, are totally captured. Releases of others which are used more widely are not. Benzene and toluene, for example, are found in high concentrations in gasoline, but since tailpipe emissions are not included in the toxic release reporting, these releases aren't counted. EPA is looking into ways it might expand the inventory reporting to include more nonmanufacturing facilities.

Federal facilities are not required to report toxic release data either, although private contractors running federal facilities are, so the majority of federal releases aren't counted. An EPA survey of federal departments and agencies shows that, with few exceptions, they have made little effort to comply with toxic release reporting voluntarily. The Department of Energy is one exception. Defense Department agencies, on the other hand, are not complying with reporting rules.

Although the agency admits it's too early to see trends, it did make an effort to compare the 1987 and 1988 data. Using what it calls matched data sets, EPA looked at releases of individual chemicals at individual facilities that reported for both years. What EPA found was that many of the decreases and some increases in the total could be traced to large changes at individual plants. All the reported decreases in arsenic releases, for example, were accounted for by one change made at the Kerr-McGee Chemical plant in Trona, Calif.

Waste minimization is a major goal of EPA and the Toxic Release Inventory has a voluntary reporting form to record minimization results. The agency reports that only 10% of the reporting facilities filed minimization forms, not enough to provide any reliable data on national waste minimization efforts or on what methods are being most commonly used. Most of the reductions that were reported were achieved by equipment changes, on-site recycling, and housekeeping improvements. Two methods that are often touted as the best means for reducing toxic pollution—reformulation of processes and substitution of less toxic raw materials—were the least used and caused the least minimization.

Copies of EPA's 400-plus-page report, titled "Toxics in the Community: National & Local Perspectives," are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (order number 055-000-00363-7), for $21 each. ☐

1991 Employment Outlook

Rebecca L. Rawls, C&EN Washington

lowing several years of short supply for these chemical professionals. **Page 39**

Career Planning

Useful information from the American Chemical Society and other organizations for individuals planning careers in chemistry or chemical engineering includes lists of services, sources of career information, and organizations that can supply guidance about chemical careers. **Page 41**

Comparing Chemists' Pay with That of Other Professionals

Just how well are chemists paid, compared with other professionals? Judging from letters to C&EN and conversations at chemical gatherings, the subject seems to be much on the minds of chemists these days. Opinions seem to fall broadly into three camps: One, chemistry as a profession doesn't pay as well as other fields that a young person considering chemistry as a career might choose as alternatives. This pay disadvantage is an important reason why so few students choose chemistry as a career. Two, chemistry doesn't pay as well as other fields, but certain people will always find it so rewarding in other ways that they will choose it as their career. And three, chemists have an exaggerated notion of how much typical practitioners of other professions earn. In reality, chemists' pay is comparable to that of equally qualified people in other fields.

In an effort to bring some useful information to the discussion, here are some comparisons of the salaries of chemists with those of people in fields that might seem alternative career choices to young people considering chemistry.

Physicians are often cited as being better paid, by and large, than chemists, and they probably are. According to an American Medical Association survey, the average net income for physicians in the U.S. in 1988 was $144,700, nearly three times the $50,000 median salary for Ph.D. chemists that year, as measured in the American Chemical Society's annual survey. (1988 is the most recent year for which AMA has data on physicians' incomes.)

Such an overall comparison, however, may be somewhat deceptive. Physicians in the survey had three or four years of college, four years of medical school, and then one to six

Some words of caution about the comparisons used in this report

The best way to compare salaries of different professions accurately is to survey a large and appropriately selected sample of people from each field at the same time, making sure to design the survey so that confounding factors, such as amount of education, work experience, age, sex, and type of employer can be taken into account in analyzing the results. No such study exists comparing chemists with the whole range of other professions discussed in this article. By and large, this article compares data from different surveys conducted by different organizations at different times and for different purposes. At best, it can give only a preliminary approximation of the relative salaries of chemists and other professionals.

One example may serve to show just how rough these approximations can be. A survey by the Bureau of Labor Statistics in March 1990 gives an average annual salary of $46,561 for all chemists working in goods-producing industries. An ACS survey, conducted the same month, found the average salary for all chemists in industry to be $55,583, which is nearly 20% higher. Among other differences, the ACS survey is of its members employed in industry, and ACS members are somewhat more likely than industrially employed chemists as a whole to have Ph.D.s. That may be one reason why the ACS survey finds higher salaries. Also, ACS includes member chemists in all industry and the BLS survey is specific to goods-producing industries. Most, but not all, of the jobs for chemists in industry are in the goods-producing sector, so the two surveys examined different populations.

Some drawbacks of the comparisons in this article deserve special mention. Usually different surveys were not carried out at the same time. The comparisons made here are always from surveys conducted in the same calendar year, but salaries can change a lot in the course of a year. The median salary of office-based physicians, for example, rose 12.5% from 1988 to 1989 according to the survey conducted by *Medical Economics.*

Some of the comparisons are of median salaries, some of mean salaries. The median is the salary at which half of the sample is paid more and half less. The mean is the mathematically derived average of the salaries in the sample. A few very high salaries can shift the mean significantly but will usually not affect the median. Thus, medians are a better measure of the typical salary of a group, and whenever medians are available, that's the comparison used here. But when the median isn't available, an average can still tell something. And for large, relatively homogeneous groups, averages and medians will be almost the same. The federal government, for example, employs large numbers of professionals at a limited number of discrete salary levels and has no extreme deviations in salary. Thus, for federal employees, average salaries provide a better measure of typical salaries than they would for all physicians, for example, or all lawyers.

additional years of residence training, depending on their area of specialty. Most Ph.D. chemists don't have that much post-high school professional training—nine years is more typical. Among physicians, the specialty that most closely matches that amount of training is the general or family practitioner. For this specialty, 1988 income averaged $94,600, still almost twice the typical salary of Ph.D. chemists.

Physicians also differ from chemists in another important factor; most of them are self-employed. Thus they carry business risks and expenses that most chemists don't. According to a survey by the magazine *Medical Economics,* the net income of typical office-based physicians in 1989 was only 53% of the gross receipts from their practices. The rest went for professional expenses. And what's left isn't really comparable to an employee's salary because these physicians also have to pay expenses such as retirement and insurance, items employers ordinarily provide in addition to salary.

In 1988, the AMA survey found self-employed physicians had an average annual before-tax income of $160,000; those who were employees averaged $113,000 in income that year. Physicians who were employees and in general practice averaged $81,600 in 1988. That's still more than most chemists were earning. The highest paid 10% of Ph.D. chemists that year made $80,000 or more. About one quarter of Ph.D. chemists with 30 or more years of experience made that much.

According to the *Medical Economics* survey, office-based physicians had a median income of $132,550 in 1989, up 12.5% from the 1988 median of $117,780. In 1989 the median income of the highest paid Ph.D. chemists—those working in industry—was $58,000, or 44% of the physicians' median. More than 90% of office-based physicians earned more than $58,000 in 1989. The median income for those in general practice was $86,860, or half again as much as Ph.D. chemists working in industry earned. In the highest earning specialty, cardiovascular surgery, office-based physicians had a median income of $296,300, more than four times the $69,500 that was the average income of Ph.D. chemists that year in their highest earning "specialty"—the petroleum industry.

The 1988 median of $117,780 found in the *Medical Economics* survey is considerably different from the $160,000 average salary for the same year found by the AMA, and it points out the difficulty of comparing data from different surveys. Among other differences, the AMA number is average income and the *Medical Economics* figure is median income.

Lawyers are another group renowned for their high incomes, leading some chemists to assume that the typical lawyer probably earns much more than the typical chemist. But here that conclusion may not be so well founded.

The American Bar Association does not survey its members regarding their income, nor could C&EN identify any other organization that surveys the income of the whole spectrum of lawyers. Nevertheless, some helpful statistics are available.

Engineers, physical scientists among highest paid faculty

Discipline	Full professor: Average salary, 1989	Full professor: % change from 1988	New assistant professor: Average salary, 1989	New assistant professor: % change from 1988
Law	$78,875	5.8%	$43,434	1.7%
Computer information	67,026	5.8	40,672	2.3
Business	66,492	6.3	48,023	8.4
Engineering	65,342	5.6	41,845	5.0
Physical sciences	59,122	5.7	34,003	8.3
Interdisciplinary sciences	57,562	6.4	27,579	3.3
Mathematics	57,237	5.3	32,858	4.5
Social sciences	56,637	6.2	30,546	7.9
Psychology	56,599	6.4	31,492	9.8
Library	56,541	6.0	32,056	6.0
Area studies	55,799	4.1	29,304	7.0
Public affairs	55,582	5.4	31,204	0.6
Biology	53,997	6.8	31,994	10.4
Architecture	53,337	4.7	32,013	7.7
Letters	53,083	6.3	27,596	7.1
Foreign languages	52,613	6.5	26,832	4.7
Communications	52,117	5.3	30,887	4.6
Agricultural sciences	51,034	5.5	32,246	7.3
Education	50,677	6.5	29,339	5.6
Home economics	50,420	3.2	31,139	5.3
Fine arts	46,819	5.7	26,667	8.0
ALL MAJOR FIELDS	$57,997	5.7%	$34,164	5.4%

Note: Data are for 1989-90 academic year for faculty at institutions belonging to the National Association of State Institutions & Land-Grant Colleges. **Source:** American Association of University Professors

According to a survey of recent law school graduates conducted by the National Association for Law Placement, the median starting salary for lawyers in 1988 was $35,000; ACS's annual starting salary survey found the median starting salary for Ph.D. chemists that year to be $40,550, or 16% more than beginning lawyers.

According to a survey by the young lawyer's division of the American Bar Association, the 1990 median income of lawyers who are up to 35 years of age or no more than three years out of law school is $65,000. ACS doesn't compile data on a strictly comparable group of Ph.D. chemists; perhaps the closest equivalent would be those working in industry five to 14 years after receiving their bachelor's degrees (which would make them about 27 to 36 years old). The 1990 median salary for this group is between $47,000 and $50,000.

Lawyers, like physicians, are much more likely than chemists to offer their services directly to the public. In the case of lawyers, this means that many are either self-employed or members of law firms. However, some lawyers do work for corporations that pay them salaries, and this is the segment of the legal profession that is probably most fairly compared with chemists who are similarly employed. The Bureau of Labor Statistics, in its annual survey of the pay of professional, administrative, technical, and clerical workers, collects data on both attorneys and chemists working in industry. This survey examines workers in goods-producing industries one year and in service-producing industries the next.

Ph.D. scientists earn less than most engineers

ALL SCIENTISTS	$47,800
Chemists	50,500
Physicists and astronomers	53,400
Mathematicians	46,600
Computer/information specialists	54,400
Earth scientists	50,800
Oceanographers	44,300
Atmospheric scientists	50,000
Biological scientists	44,500
Agricultural scientists	44,300
Psychologists	44,300
Economists	50,800
Sociologists and anthropologists	41,700
ALL ENGINEERS	$58,100
Chemical	58,900
Civil	53,300
Electrical	60,500
Mechanical	55,700
Nuclear	58,900

Note: Median annual salaries for doctoral scientists and engineers in 1987. **Source:** National Science Foundation

The March 1990 survey of goods-producing industries found an average salary for chemists of $46,561. BLS divided the jobs of chemists into seven levels based on education requirements, duties of the job, and supervisory responsibilities. Disregarding the levels generally held by people with less than a Ph.D. raises the average salary for chemists in the survey to $57,763. Attorneys' salaries, which were divided into six levels, averaged $76,937 overall, or 33% more than chemists.

Comparison of salaries at the job levels BLS considers most equivalent finds attorneys consistently paid more than chemists by amounts that vary from 4 to 14%. The overall difference in average salary is greater than these level-by-level comparisons would suggest because the highest job level for attorneys is one higher than for chemists. Thus, the highest paid attorneys earn, on average, 40% more than the highest paid chemists do.

BLS's 1989 survey of service-producing industries found too few chemists to measure in four of the seven job levels, since chemists working in industry by and large do so in the goods-producing sector. Chemists at two of the three levels measured earned more than attorneys at the comparable level, about 5% more in each case. Last year, salaries for chemists and attorneys were the same at the third level.

Anecdotal evidence suggests that lawyers' incomes vary enormously, probably much more than those of chemists or people in most other professions. According to an annual survey conducted by *American Lawyer* magazine, partners in the largest law firms in the U.S. often earn over $1 million per year. In 1989, for example, the 197 partners in the New

York-based firm of Skadden, Arps, Slate, Maegher & Flom averaged $1,195,000 in income. Even the starting salaries at New York law firms dwarf the salaries of typical chemists—these averaged $71,361 in 1988, according to the National Association for Law Placement. Ph.D. chemists working in industry needed 30 years' experience for their 1988 average salaries to be that high. But the attorney general of the state of Montana doesn't make that much, either ($47,166 in February 1990, according to the *National Law Journal;* the attorney general of Arkansas makes $26,500), nor does the highest paid lawyer in many public interest organizations ($66,000 at the American Civil Liberties Union and $70,000 at People for the American Way, according to the same *National Law Journal* survey).

U.S. attorneys make $81,400 in 1990, their assistants make from $24,700 to $78,200. Such salaries begin to seem more like the kind of income chemists can expect to make. All attorneys working for the federal government in civilian, full-time employment in September 1989 had an average income of $54,049, according to the federal Office of Personnel Management. Ph.D. chemists working for all government (state and local as well as federal) averaged $54,200 that same year, according to the ACS survey.

A third profession often held to pay better than chemistry is engineering. According to a 1987 survey by the National Science Foundation, engineers in all fields with Ph.D.s had a median salary of $5[illegible],000, 15% more than the $50,500 median for chemistry Ph.D.s found in the same survey. Chemical engineering Ph.D.s had a median annual salary of $60,900, 5% more than engineers as a whole and 21% more than Ph.D. chemists.

More recent data from the Engineering Manpower Commission finds the 1990 median annual salary of engineers working in industry to be $63,650. According to the ACS survey, chemistry Ph.D.s working in industry in 1990 had median salaries of $60,000, or 7% less. At the master's level the median salary for chemists in industry is $47,200, 13% less than engineers with a master's degree. And at the bachelor's level, chemists in industry earn a median salary of $40,000, 11% less than engineers with a bachelor's degree. Although these data suggest the same general relationship between salaries in the two professions as the NSF survey does, they give a less reliable comparison between the two fields, because they come from two different surveys.

If the typical engineer earns somewhat more than a typical chemist with the same amount of education, university professors in fields like the humanities usually earn less than their counterparts in chemistry or engineering. According to a report from the American Association of University Professors, full professors in the physical sciences (which include chemistry) at state universities earned an average of $59,122 for the 1989–90 academic year. That's 17% more than full professors of education in the same schools, 12% more than foreign-language professors, and 11% more than professors of letters, but within 2% of the $57,997 average salary for full professors in all major fields at these schools. Full professors of engineering earned $66,342, or 10% more than physical science professors. Only law, computer information, and business professors received higher salaries than engineering professors in this survey, with average salaries of $78,875 for law (33% more than physical science professors), $67,026 for computer information professors (33% above physical scientists), and $66,492 for business (12% more than physical sciences professors).

These field differences are also found among starting salaries for tenure-track positions at these schools. New assistant professors in physical sciences averaged $34,003 in this survey, very similar to the $34,164 average for all major fields. Engineering assistant professors start at $41,845, or 23% more than their physical sciences colleagues. New assistant professors in business had the highest salaries, on average 41% more than physical scientists. In education, they earned 16% less than their physical sciences colleagues, in foreign languages 27% less, and in letters 19% less.

In its 1987 survey, the National Science Foundation found that the $50,500 median annual salary of Ph.D. chemists was 6% more than the $47,800 median for all Ph.D. scientists. Only physicists and astronomers (considered a single group with a median of $53,400), computer specialists ($54,400), and economists ($50,800) earned more, among the 15 science fields surveyed. The poorest paid fields were sociology and anthropology, which, with a median salary of $41,700 was 21% below the median for chemists, and psychologists and agricultural scientists, each with median salaries of $44,300, 14% less than chemists.

A 1989 salary survey of members of the American Institute of Physics found the median annual salary for Ph.D. physicists employed in industry to be $63,500, or 9% more than the median for Ph.D. chemists working in industry as measured by the ACS survey of the same year. The median starting salary for new doctoral physicists in 1989 was $42,480, according to a separate AIP survey of starting salaries. ACS's starting salary survey for Ph.D. chemists that year indicated their median salary was a very comparable $42,000. Similar to the situation with chemists, new doctoral physicists were paid the most in industry, where the median salary was $48,720. For chemists, the median salary for new Ph.D.s going into industry that year was $42,950, or 13% less than physicists.

The American Psychological Association's 1989 survey of its members found the largest single category of Ph.D.-holding psychologists to be those who provide direct human services. The median annual salary of this group was $55,000.

A 1988 survey conducted by the American Institute of Architects found the median annual salary of architects in firms to be $39,000. Starting licensed architects had a median salary that year of $28,000. Such architects rarely have Ph.D.s, according to AIA. Instead, a typical professional education includes five or six years of post-high school study at a university followed by a three-year internship in an architectural firm. Passing a licensing examination is also required. □

Demand

An economic downturn, decline in chemical earnings, and the Middle East crisis may lead to a wait-and-see attitude among employers

Predicting in the autumn what demand for chemists and chemical engineers will be over the coming academic year is always a challenge. This year it's even more so. Following a year when demand was strong for chemists and even stronger for chemical engineers, the fall recruiting season finds the U.S. economy in a downturn, perhaps at the start of a recession. Earnings for chemical companies as a group have declined for each of the past four quarters. And overshadowing everything else is the possibility of armed conflict involving the U.S. in the Middle East.

The employment outlook "starts out with a big 'if,' " says one chemical company recruiter candidly, "and that 'if' is spelled I-r-a-q."

Open hostilities in the Middle East will hurt chemical employment, most observers predict, although even that prediction is qualified. Short-term higher profits for oil companies might be used to expand R&D, and if oil prices could be expected to stay high, it would stimulate alternative fuels development and create jobs for both chemists and chemical engineers. Some chemical company recruiters are waiting to see if the oil companies will be making more and higher-priced offers, especially to chemical engineers, who are already in high demand. For the most part, though, they fear fighting in the Middle East, if it occurs, will jeopardize supplies of petrochemical feedstocks and further damage chemical companies' profitabilities.

In times of uncertainty, cautious employers "hide and watch," as Rebecca J. Simon, placement director at the University of Illinois' school of chemical sciences, calls it. They may recruit aggressively, but they wait to make firm offers. That's the kind of recruiting year this may be shaping up to be, she says. It will be a very busy recruiting fall at Illinois, with the number of recruiters scheduling visits about the same as last year, "but we'll see how many offers come in in March or April."

She recalls the last downturn in chemical employment, which occurred in 1982 and 1983. The 1981-82 academic year also began with strong company recruiting in the fall, but when the year was over, offers for bachelor's-level chemical engineers nationwide had fallen from 7500 the year before to about 4000. A year later, they were down to about 1150, according to data collected by the College Placement Council.

"It's a confusing time," agrees Joan E. Wheeland, coordinator of the American Chemical Society's employment and career services, which operates the ACS National Employment Clearing House. Over 200 organizations conducted 2900 interviews during the ACS national meeting in August in Washington, D.C., making it one of the busiest clearinghouses ever. "From the number of interviews taking place, there are certainly jobs out there," Wheeland says. Still, she senses from recruiters and applicants alike an uneasiness that the strong demand for chemists and chemical engineers that has characterized the past several years may not continue much longer.

"I see companies hedging," says James D. Burke, manager of professional recruiting for Rohm & Haas research. He expects companies to cut back a bit in their hiring for both bachelor's and advanced degree applicants and in both chemistry and chemical engineering. As recently as the August ACS meeting, recruiters from many of these companies were saying they planned to increase their hiring somewhat at the Ph.D. level in 1991.

Rohm & Haas' current recruiting plans are "about a carbon copy of last year's," in both fields and at all degree levels. These plans, like those of most firms, will be reevaluated in the winter in light of the company's year-end performance. "I don't see our goals increasing from last year," Burke says, "but we sure do plan to hire." As he sees it, the U.S. economy may be easing into a recession, but Europe's isn't, nor are the economies in Japan and the other high-technology countries of the Pacific Basin. Thus, chemical exports are likely to remain high. Though earnings are down for many chemical firms, sales continue to set record highs, making the long-term outlook hopeful, barring the unknown effects of conflict in the Middle East.

Monsanto, too, plans to hire both chemists and chemical engineers at about the same level as last year, says Robert J. Mason, corporate director of university relations. Altogether, the company's five operating units and corporate research will hire some 65 chemists and chemical engineers at all degree levels. There will be fewer openings in the company's agricultural chemicals area, which is being reorganized, but a corresponding increase in jobs to be filled in the chemicals area, particularly for chemical engineers. The modest increase expected there will be for training people to replace older workers who will be retiring in the next few years, explains Joe Wiley, manager of professional employment for Monsanto Chemical Co. That increase may be trimmed back if the economic outlook worsens, he adds.

Du Pont already has slightly trimmed its hiring plans for both chemists and chemical engineers. "When business goes down, we tend to be more cautious about hiring," says Robert K. Armstrong, manager of professional staffing, and this seems to be such a time. Overall, the company plans to reduce hiring of both chemical engineers, which it hires primarily at the bachelor's level, and chemists, where by far the most jobs are for Ph.D.s, by 10 to 15%. Chemical engineers have been in such tight supply in recent years that Armstrong expects they will continue in high demand this year, despite the current level of caution among employers. "Ph.D. chemists are not in bad shape either," he says. "In both cases, good candidates will be sought after."

If chemical company profits don't soften further, recruitment by Union Carbide this year will probably be about the same as last year, says Thomas J. Neelen, manager of professional placement for that company. For Ph.D. chemists, that means a continuation of two years of relatively strong demand, where "the supply/demand curve was in favor of the candidate." Last year was a rather typical year for chemical engineering recruitment for Neelen's company. The 1988–89 year was one of its biggest recruiting years for chemical engineers, particularly at the bachelor's and master's level, and last year began with the same level of aggressive recruitment. By December, however, weakness in commodity chemicals markets, in particular, caused the company to cut back its spring recruiting efforts.

More Ph.D.s in chemistry and chemical engineering, but bachelor's degrees in both fields are declining

	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
Academic year	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1978	11,474	1892	1525	4615	1237	259
1979	11,643	1765	1518	5655	1149	304
1980	11,446	1733	1551	6383	1271	284
1981	11,347	1654	1622	6527	1267	300
1982	11,062	1751	1722	6740	1285	311
1983	10,746	1604	1746	7145	1304	319
1984	10,704	1667	1744	7475	1514	330
1985	10,482	1719	1789	7146	1544	418
1986	10,116	1754	1908	5877	1361	446
1987	9,661	1738	1976	4983	1184	497
1988	9,025	1694	1990	3926	1103	579

Source: National Center for Education Statistics

Although current plans are for strong hiring this year, a similar revision could occur at several companies this winter. One possible scenario if the economy should worsen, Neelen suggests, is for companies to decide in December that they have already talked to enough applicants on campus for the positions they will have available. "I have some very considerable concerns about a worldwide economic downturn ... or a negative development in the Middle East," he says. "My advice to college seniors would be to get campus interviews in as early as possible, and not rely on companies coming back in the spring."

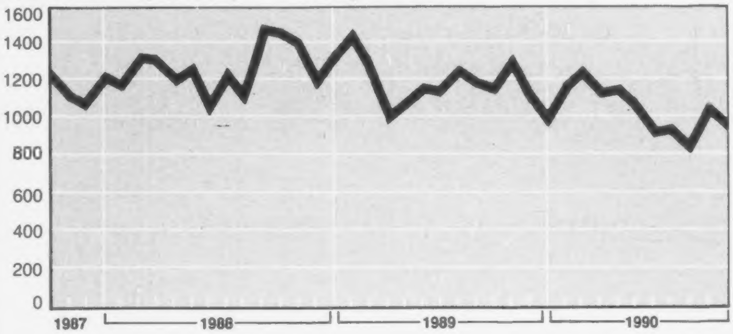
Similar advice comes from Joseph Schewe, manager of professional employment for PPG Industries. Students should "be a bit aggressive in the fall" and get a firm job offer if they can, he says. Demand for both chemists and chemical engineers looks fairly healthy so far, though he admits to having his fingers crossed about how long it will continue. PPG plans to hire more chemists and chemical engineers this year than last at the bachelor's level, where most of the firm's hiring occurs. Unlike some other chemical employers, PPG's sales and earnings for the first two quarters of 1990 were the strongest in its history and these are fueling its recruitment efforts.

If developments in the Middle East don't change its plans, Phillips Petroleum will be hiring about the same number of chemical engineers this year as the past year as well as "a handful" of chemists, says director of employment and placement William F. Dausses. The company, like many oil companies, has been aggressively recruiting chemical engineers for several years to help build new refineries and redesign older ones to meet new liquid emissions regulations. Pollution concerns also are requiring the reformulation of gasoline, which requires changes at the refinery.

Phillips has no plans at this time to expand its R&D effort, which is where most of the company's Ph.D. chemists and chemical engineers work. Current high oil prices, brought on as they have been by the prospect of military action in the

Help-wanted ads have been declining since early 1988

Volume of C&EN "positions open" advertising,[a] column-inches



[a] Column-inches published during consecutive periods of four weeks each; no issues were published in last week of 1987, 1988, and 1989.

Middle East, don't necessarily mean increased profits in the long run for oil companies, in the company's view. "That could go either way," Dausses says. "The higher oil prices go now, the lower they'll go when the hostilities are over—whether that's in two months or 10—because there will be more production." But if disruptions in supply lead to an economic recession, demand for chemists and chemical engineers will go down.

If it can find them, Exxon hopes to hire as many as 25% more chemical engineers this year, says Susan Ottsen, technical recruiting coordinator for Exxon Co., USA. With fewer students expected to graduate this year than last with chemical engineering degrees, she predicts demand will stay high. Exxon was unable to hire as many chemical engineers as it wanted last year, which partly accounts for the company's higher recruiting targets this year. Demand for chemists, who Exxon hires primarily at the Ph.D. level for R&D positions, will be about the same as last year, she says.

Nalco Chemical, like a number of other specialty chemical producers, has seen its earnings rise during the past year. But that's not translating into more jobs for chemists. The company had a major expansion of its R&D staff last year and won't be hiring quite so aggressively this year, though it still expects some 20 to 30 openings for Ph.D. chemists during the year, according to Karen Nordquist, manager of technical employment. Last year, the company sought roughly twice that many. "We were able to fill all the expansion positions," Nordquist says, "and we saw good applicants."

Although earnings at Merck—and pharmaceutical companies generally—have held up much better than for chemical producers during the past year, that company will be cutting back a bit in its plans for hiring chemists this year. Last year the company hired 75 to 100 chemists. "We're trying to stem our growth in R&D staff, which has been occurring at about 10% per year," explains Teresa Merinelli, manager of college relations for Merck. This year, Merck aims to expand the R&D staff 7.5%. It also plans to hire some 50 to 75 engineers—mostly chemical engineers—which is slightly fewer than last year.

Upjohn will be hiring some chemists this year, perhaps 12, up a bit from last year, but not at the levels of 30 to 40 per year that the company had in 1986 to 1988, according to recruiting representative Marinus Dejong. In addition to staff replacements, the positions include some expansion in Upjohn's fine chemicals division, in anticipation of expanding markets in this area in Eastern Europe.

Despite expressions of concern about how long it might last, the picture in university placement offices this fall is definitely one of heavy recruitment for both chemists and chemical engineers. At the University of Wisconsin, for example, the number of companies that signed up to recruit Ph.D. chemists this year is the same as last, which was a very good recruiting year, according to chemistry department placement coordinator, Audrey L. Aylesworth.

More organizations have scheduled interviews this year at the University of California, Berkeley's career planning and placement center, says Linda Lewis, technical career adviser for chemistry and chemical engineering there. This center handles the bulk of bachelor's level interviews at the university. Demand is up particularly for chemical engineers. "We've not seen a lot of cancellations, Lewis says. If anything, demand is picking up for chemical engineers at Wisconsin, says Sandra Arnn, director of career planning and placement at the college of engineering. Traditional chemical companies, as well as pharmaceutical, petroleum, and environmental firms all seem to have growing needs for chemical engineers at a time when enrollments are declining. The result is a student's market, in which many graduates had three or four job offers last year and the average salary offered rose 15% from the year before. As many as 25% of last year's graduates also received supplemental payments "in the $1000 to $2000 range" to encourage them to go to work for particular employers, Arnn says.

Chemical engineering graduates at the University of California, Los Angeles, averaged six offers per student last year, according to Manuel Perez, director of engineering and science placement there. This demand is definitely continuing, he says, fueled—particularly in California—by the expanding market for environmental firms. Traditional engineering companies also are expanding their chemical engineering recruitment, as their business shifts increasingly to constructing plants that meet tighter pollution controls. The demand is even spilling over to bachelor's level chemists, he says, who are being hired in some cases to fill chemical engineering positions where engineering graduates can't be found. □

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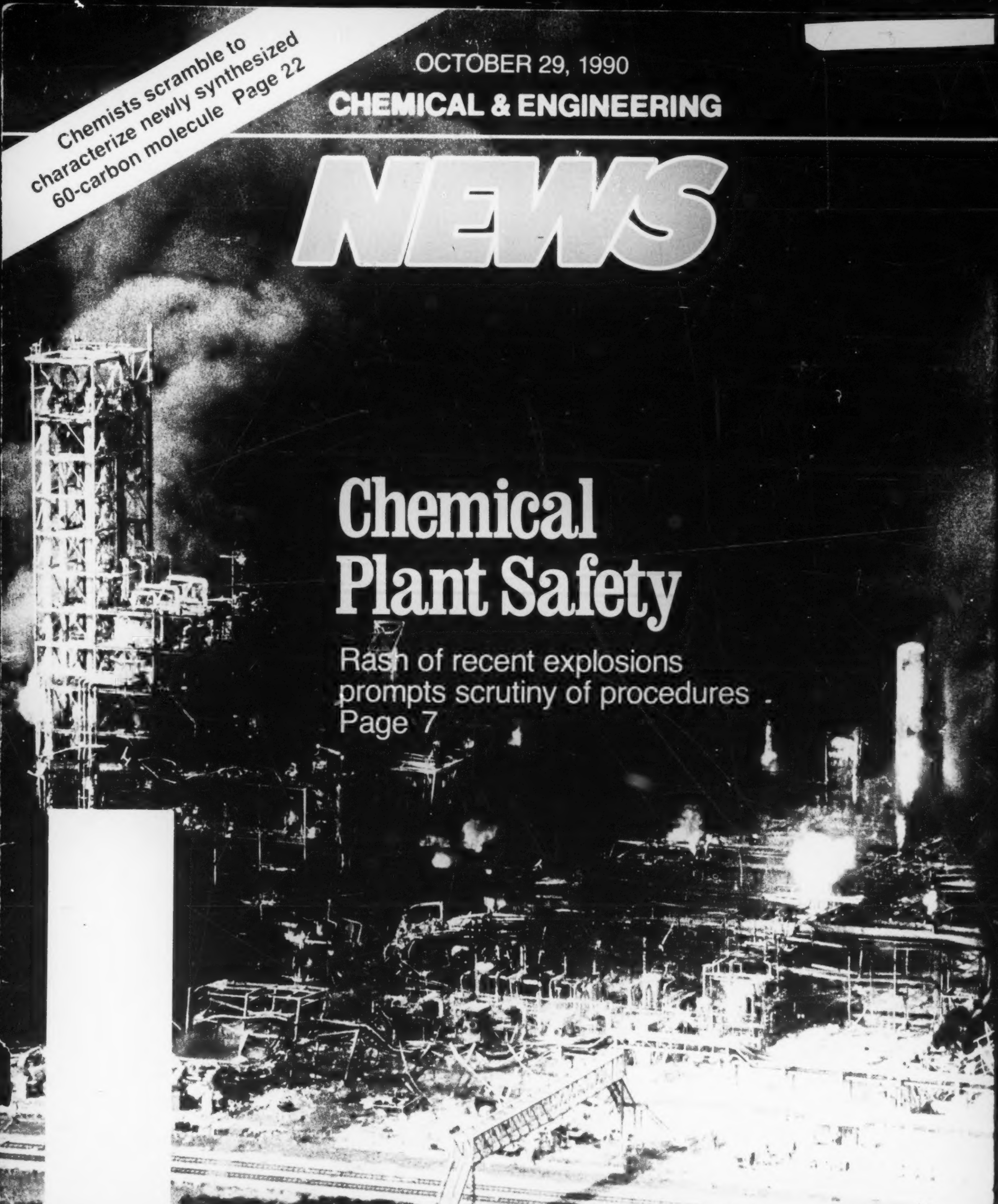
CHEMICAL & ENGINEERING
NEWS

Chemists scramble to characterize newly synthesized 60-carbon molecule Page 22



Chemical Plant Safety

Rash of recent explosions prompts scrutiny of procedures
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CHEMICAL & ENGINEERING NEWS

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- **Federally funded R&D activities are faring well in 1991 budget, with all agencies funded so far getting increases.** **Page 5**
- **Monsanto scientists conduct successful first field tests of genetically altered cotton that produces a protein toxic to many caterpillar species.** **Page 6**
- **Worst of drop in profits for petrochemical makers may be over, with easing of crude oil prices and gradual increase in some product prices.** **Page 6**

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Cover: Explosion and fire at Phillips 66 polyethylene facility in Pasadena, Tex., in October 1989. Photo by *Houston Chronicle*

News Focus

Recent spate of plant explosions has heightened concern over the safety of petrochemical plant operations, prompted action by business, government, labor, and other groups. **Page 7**

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LETTERS

California Proposition 128

In the article on California Proposition 128 (so-called "Big Green") by Rudy Baum (C&EN, Sept. 24, page 7), the author says, "They can be forgiven for their lapse in civic responsibility because the act is numbingly legalistic. But understanding its provisions is important, because if they become law, they will affect virtually every aspect of life in the state."

Unfortunately, it is highly unlikely that they will understand this initiative at all, based upon our experience with the actual provisions of a previous initiative, Proposition 65. Its requirements are poorly understood right now, after it has become law. I am currently taking a graduate-level environmental engineering class, and my classmates who are practicing environmental engineers do not understand the provisions of Proposition 65. The layman is going to be totally confused.

As I write this letter, I still have not received my booklet from the Secretary of State containing the text of all of the measures on the ballot. Based upon past experience, I won't get that package until one week before the election. That gives me one week to read all of the material and try to reach some sort of intelligent decision. The average person won't even give it that much effort, because the text of the initiatives is straight legalese, and very difficult to read.

So the vast majority of the voters rely on the TV advertisements to get their information. The TV news and the newspapers won't devote more than a token effort to any initiative, because it is so boring, and the sports scores will sell more advertising. The legal initiatives are judged just as any candidate would be—on popularity and having the right buzzwords.

If the picture that I'm painting depresses you, it should! California's citizens may be getting the kind of government that we deserve, to paraphrase Winston Churchill, but those of us who desire to understand what it is that we are voting on are thwarted at every step.

In order to reach everybody who cares to pay attention, a very complicated issue must be explained in simple words and less than 30 seconds (the length of a TV commercial). The spokesperson must not be tainted by any connection to a chemical industry (they will be labeled as stooges and dupes anyway by the environmentalists). The whole situation precludes any understanding of technical issues, because they are complex by their very nature.

My prediction is that Propositions 128 and 130 will pass because they appear to be doing something to improve the environment. Since the majority of voters in California are in the Los Angeles and San Francisco metropolitan areas (urban people, removed from the realities of farming, timbering, and oil production), the initiatives can be passed solely on the votes of people with little or no knowledge of the impact.

The writing is on the wall: California is going to be an increasingly difficult place for chemical professionals to work. Our electorate is allowing itself to be misled on environmental issues by virtue of the very emotional nature of these problems. The result of this political mess is economic recession, which is already here. If we continue to emplace poorly worked out, technically unfeasible legislation, the future will be very bleak indeed. California—and the world—needs real, well-designed solutions to our environmental problems, not knee-jerk actions written by people detached from the consequences of their actions.

Eric A. Anderson
Pasadena, Calif.

Science education

In an article by James Krieger (C&EN, June 11, page 27) many of the problems that science education in general and chemistry in particular now face were highlighted. One problem often cited is that the current general chemistry curricula need major overhauling. Most students who take chemistry are nonchem-

Corrections

- Oct. 15, page 77: On the registration form of the 1990 ACS SE/SW Regional Meeting, a footnote to the $10 student registration fee indicates that this fee includes tickets to the Jazz Party. This is incorrect—an additional $25 is required to attend the party.
- Oct. 22, page 40: The 1990 ACS starting salary survey found the median starting salary for Ph.D. chemical engineers to be $50,000, which is 6% more (not less) than the 1989 median. Women chemical engineers at the bachelor's level start with 1% lower median salaries than men; at the master's level, women's median starting salaries are 2% higher than men's.

by 10 million tons annually. Nitrogen oxide emissions also will be reduced by 2 million tons to 4 million tons annually after 1997.

The acid rain program imposes a cap on emissions that affects all utilities, and is designed to preserve gains achieved. In addition, the program sets up a trading system, under which utilities making deep cuts earn credits of up to $500 for each ton of reduction. They can use these credits to build additional capacity or sell them to other utilities.

Some 15,000 miners of high-sulfur coal in the Midwest and Appalachia may lose their jobs as a result of this legislation. To protect them and others thrown out of work by the tightened regulations, the bill provides $250 million over five years for extra unemployment benefits, as long as a displaced worker remains in a retraining program.

Provisions for protecting the ozone layer are new to this revision and do not appear in the 1977 law. Production of ozone-destroying chlorofluorocarbons and carbon tetrachloride is to be halted by 2000. Production of methyl chloroform is outlawed two years later. Safer hydrochlorofluorocarbons are to be phased out after 1994, and their production is banned in 2030.

Automakers and oil companies are required to help curb smog through tighter controls on tailpipe emissions. Among the many provisions affecting them, automakers will have to begin in 1994 to phase in new cars emitting 60% less nitrogen oxides and 40% less hydrocarbons. Pollution control equipment will have to be built to last 10 years or 100,000 miles, instead of the current five years or 50,000 miles. Oil refiners will have to supply cleaner burning reformulated gasoline to the nation's nine smoggiest cities by 1995.

The American Petroleum Institute says it would like to meet the requirements of the new bill but doesn't know how to do it with existing technology. Richard E. Ayres, chairman of the National Clean Air Coalition (composed of environmental groups), claims the new bill's provision on urban smog "provides too long for too many to do too little."

No sector, industrial or environmental, is entirely happy with the bill. But all agree with Robert A. Roland, president of the Chemical Manufacturers Association, that "it will lead to continued progress in cleaning our nation's air." Ayres' coalition parts with Roland when he adds, "this continued progress won't come without a very high price."

Some noted economists deem the price too high and in a letter ask President Bush to veto the bill. However, the President is expected to sign it.

Lois Ember

Federal R&D funding generally up for 1991

Fiscal 1991 promises to be not a bad year at all for the majority of federally funded R&D activities. That's contrary to what might have been expected in a budget year that sees Congress and the Administration tying themselves in knots trying to come up with mutually agreeable ways of reducing the federal deficit.

At press time, Congress had completed work on all but two of the appropriation bills that fund federal R&D agencies. Remaining were one covering defense-related activities and another funding the Department of Interior and some Department of Energy programs.

Moreover, all of the agencies funded so far are getting increases—in some cases quite substantial ones for a time of "austere" budgets. For example, funding for the National Institutes of Health is up $710 million, or 10%, to just under $8 billion. Congress believes the amount it has provided for NIH "is sufficient to fund grants at the levels approved by the Institutes with no arbitrary downward negotiation of awards."

Not all programs within an agency are slated for equal increases. For example, funding for the DOE's basic energy sciences activities is up 23% to $716 million. But within that category, funding for chemical sciences is up just 10% to $159 million, while materials sciences is up 36% to $277 million. The materials sciences budget includes an additional $12 million over fiscal 1990 for work on the advanced neutron source at Oak Ridge National Laboratory.

Congress also provided a total of $243 million for DOE's Superconducting Super Collider. That's 12% more than the SSC project was allotted in fiscal 1990, but almost 25% less than the Administration wanted this year.

Overall funding for NSF is up 11% to $2.3 billion. Education and human resources activities are up

Research gets healthy increase in 1991

$ Millions	1991 Congress final	1991 Administration request	1990	% change 1990-91
NIH	**$ 7,987.2**	**$ 7,623.2**	**$ 7,276.8**	**10%**
NASA R&D	**6,023.6**	**7,074.0**	**5,227.8**	**15**
Energy	**3,675.8**	**3,379.0**	**3,283.2**	**12**
Supply R&D	2,527.1	2,105.3	2,184.4	16
General science & research	1,148.7	1,273.7	1,098.8	5
NSF	**2,316.0**	**2,383.0**	**2,080.6**	**11**
Research-related activities	1,694.2	1,954.0	1,592.8	6
USDA	**1,116.5**	**1,003.0**	**979.6**	**13**
ARS[a]	665.1	656.1	596.8	11
CSRS[b]	451.4	346.9	382.8	18
Commerce	**422.3**	**397.9**	**334.6**	**26**
Oceanic, atmospheric research	207.0	199.5	172.8	20
NIST[c]	215.3	198.4	161.8	33
EPA[d]	**254.9**	**249.0**	**229.6**	**11**
TOTAL	**$21,796.3**	**$22,109.1**	**$19,412.4**	**12%**

a Agricultural Research Service. b Cooperative State Research Service. c National Institute of Standards & Technology. d Fund for extramural R&D. **Source:** Congressional budget documents

58% to $322 million, and academic research facilities are up 4% to $20.5 million. Funding for NSF's research grants and related activities is up 6%. The Administration had sought a 15% increase, to just under $2 billion.

On a somewhat ominous note, Congress has directed NSF to arrange for a study by the National Academy of Sciences on the way NSF selects proposals for funding. Congress is particularly interested in the role played in "the decision process of merit review by outside scientists and executive agency staff."

Janice Long

Insect-killing cotton passes field tests

Successful first-year field trials have been carried out on cotton genetically altered to resist insect damage. The tests show that its use might allow a 35 to 40% reduction in insecticide applications on cotton, and the developer, Monsanto, hopes to improve the cotton to reduce pesticide use 80%.

Monsanto scientists prepared the test plants by inserting a gene from a commercially available natural bacterium, *Bacillus thuringiensis kurstaki*. The gene enables Bt to make a protein toxic to many caterpillar species, and the transgenic cotton makes a similar protein.

Monsanto conducted the field tests in six states in cooperation with the U.S. Department of Agriculture and several universities. "Nearly all the caterpillars died within four days," notes a USDA plant geneticist. The transgenic plants were about as bug-free as regular cotton sprayed with insecticide.

Monsanto's efforts to exploit biotechnology have not always been immediately successful. The company's effort to develop bovine somatotropin, a cow hormone that boosts milk production, has met resistance from farmers and government regulators. But the firm's foray into plant genetics has met with greater acceptance. According to David Altman, a geneticist at USDA's Southern Crops Research Laboratory in College Station, Tex., Monsanto's transgenic cotton "could provide additional pest control options for cotton growers."

About 15 million lb of pesticides are applied annually to the U.S. cotton crop, costing about $230 million, according to a Monsanto spokesman. Of this, 6 million lb are applied to control the type of caterpillars that the genetically altered cotton can repel. Caterpillars affected include the tobacco budworm, cotton bollworm, pink bollworm, and beet armyworm. However, the adult boll weevil, a major cotton pest, is unaffected.

Monsanto is not a major producer of insecticides, so use of transgenic cotton would not reduce its agricultural sales. Synthetic pyrethroids are now used to control caterpillar damage on cotton crops, notes a Monsanto spokesman, but the pests can build up tolerance to these frequently applied insecticides. Many growers spray more than 10 times a season. The genetically modified cotton would require fewer pyrethroid applications, and allow increased efficacy from the pyrethroids.

In addition, the transgenic plants are toxic only to the caterpillars that feed on the plants, and have no effect on humans or beneficial insects. Although Bt has been commercially available for the past 30 years, only frequent applications effectively controlled crop damage because it breaks down on exposure to light and readily washes off. The transgenic plants avoid these problems.

The altered plants pass the Bt gene on to succeeding generations through their seed, Monsanto explains. But because the firm is not a major seed producer, it plans to license the technology to produce the genetically altered cotton to cottonseed producers. It hopes commercial quantities of seed will be available in the mid-1990s. Although transgenic cottonseed will cost more than unaltered seed, the difference should be more than made up by reduced pesticide applications, says Monsanto.

Marc Reisch

Petrochemical profit decline may be easing

The full impact of the Persian Gulf crisis on U.S. petrochemical makers remains uncertain. However, there are indications the worst of the decline in profit margins since Iraq's invasion of Kuwait on Aug. 2 may be over. Crude oil prices—and with them feedstock prices—are easing, and product prices, although still lagging, are gradually rising.

Oil prices have taken a roller coaster ride since the invasion, declining recently to less than $29 per barrel, after more than doubling to as much as $41 per bbl earlier. Spot prices of natural gas-derived light hydrocarbon feedstocks, such as ethane and propane, also recently have dropped.

During the past three months, U.S. producers have raised prices for most basic petrochemicals and derivatives, such as plastics. However, the increases have lagged far behind the soaring prices of crude oil and light hydrocarbon feedstocks, squeezing profit margins. The effects have shown up as substantial declines in third-quarter earnings.

For example, ethylene and propylene prices rose less than one third while oil prices doubled. Ethylene for October delivery will be about 28 cents per lb, according to Gulf Coast industry sources. And quotes for November delivery range between 30 and 33 cents per lb.

Moreover, marketers of major volume plastics have announced price increases of 3 to 5 cents per lb for November, following increases this month—reflecting higher monomer costs. Demand for these plastics jumped in August as sales and captive use rose about 5% or more over August 1989, except for polystyrene (up just 0.3%).

However, if last week's lower oil prices hold, proposed increases in prices of chemicals could be rescinded. If crude oil holds in the $25- to $30-per-bbl range, for example, ethylene prices will stabilize at 30 cents per lb or less, industry sources say. And if war seems less likely, liquidation of plastics inventories could exert pressure on plastic prices.

Bruce Greek